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Surveys of Soviet-Bloc Scientific ond Iechnical Literature

SOVIET BIO-ASTRONAUTICS AND MANNED SPACEFLIGHT

Programs, Organization, and Personalities

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Surveys of Soviet-Bloc Scientific and Technical Literature

SOVIET BIOASTRONAUTICS AND MANNED SPACEFLIGHT

Programs, Organization, and Personalities

Comprehensive Report

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SOVIET BIOASTRONAUTICS AND MANNED SPACEFLIGHT

Programs, Organization, and Personalities

INTRODUCTION

The purpose of this report is to provide information obtained from Soviet open source literature on organizations, facilities, and personalities of the Soviet bioastronautics and manned spaceflight programs. The majority of the 700-odd bibliographic entries listed at the end of this report consist of articles from Soviet scientific and technical periodicals. A large number of articles come from special collections, such as the Problems of Space Biology series, published by the Academy of Sciences USSR, and Aviation and Space Medicine, published jointly by the All-Union Physiological Society of the USSR and the Academy of Medical Sciences USSR. In addition, the materials on which this report is based include papers presented by Soviet scientists at various international space meetings, such as the Congresses of the I. A. F. (International Astronautical Federation), COSPAR, and others. Newspaper articles, some from non-Soviet sources, make up a small minority of the references.

The Soviet space program is very extensive and apparently very flexible. The number of scientific organizations and scientists involved, even in the bioastronautics part of the program, is very large. Because most of the information concerning the organization of financing of the program is classified, the participation of organizations and individuals must be deduced. The degree of involvement, or participation, in the program is not always easy to determine. Some individuals, such as the cosmonauts and V. I. Yazdovskiy, their personal physician, are obviously an integral part of the manned spaceflight program. Scientists in charge of the selection and training of the cosmonauts are also integral to the program. Still other scientists, like Antipov and Zhukov-Verezhnikov, can be considered to be working in direct support of the scientific aspects of the space program. Their participation involves the preparation of experiments for spaceflight and analysis of the data obtained from such experiments. In such cases it is not always easy to determine whether they are assigned to the space program from their Institutes, or whether their Institutes have contracts with the space program. Nor is it easy to determine whether they do their work at their home Institute or at some other location.

A third, even larger group is involved in basic research to back up the space experiments or to prepare for future experiments. It is assumed that the scientists in this group perform most of their work within the framwork of their own organizations. Specialists to whom some specific problem related to spaceflight experiments is farmed out must be considered members of this group. However, a man who is asked to solve some scientific problem within his speciality today may be called in as a consultant to

direct a space experiment a year or two from now. The distinction between the second and third types of participation is usually quite difficult to make, but certain criteria can be established. If a scientist's name appears in a description of direct spaceflight experiments, or if he appears to work with many groups from different institutes, it can be inferred that he is working in direct support of the space program. In such cases, as a rule, no association with an institute is listed after his name. If a man's name always appears with the name of a given institute, then it can be inferred that he falls in the third category, and that his function is to provide basic research for present experiments or preparation for future ones. His relation to the space program may be considered a contractual one.

There is also a fourth category of participation. This includes scientists who have no direct connection with the official program, but who would like to climb onto the bioastronautics and the spaceflight bandwagon. Some of these have managed to attain a semi-official status in relation to the program by having their papers published in Problems of Space Biology. Such publication amounts to recognition by the Board of Editors of Problems of Space Biology, who happen to be the leaders of the Soviet bioastronautics program, that the work of this particular scientist has value for the official program. Such recognition, however, does not confer official status in the program.

Cosmic biology and cosmic medicine (terms by which the Soviets usually refer to what we call bioastronautics) evolved gradually out of aviation medicine. As rocket technology made it possible for men to reach the edge of space, it was quite natural that the men (in institutions like the Military Medical Academy imeni Kirov in Leningrad and the Scientific Research Institute of Aviation Medicine in Moscow) who had been concerned with high-altitude physiology and had been designing high-altitude pressure suits, should turn to the design of spacesuits and to the problems of selection and training of cosmonauts. It was equally natural that when the Soviets began to make experiments with animals in rocket flights in the early 1950's, the biomedical support for the program should be centered in the research facilities of the Military Medical Academy in Leningrad and the Scientific Research Institute of Aviation Medicine in Moscow. Since the majority of these biomedical specialists were, or had been, flight surgeons, it was equally natural that they should turn to the institutes of the Academy of Medical Sciences for scientific support.

At that time, in the mid 1950's, before Sputnik-I opened the space age, scientifically speaking bioastronautics was not quite respectable. There was an aura of interplanetary science fiction about it. It smacked a little of scientific social climbing. Experiments with animals in vertical rocket flights did not warrant the august attention of the members of the Department of Biological Sciences of the Academy of Sciences USSR. So the pioneer work of experiments with animals in vertical rocket flights went by default, as it were, to scientists at the institutes of the Academy of Medical Sciences and the Institute of Aviation Medicine.

For the first two or three years of the space age the Academicians tended to regard bioastronautics as something slightly parvenue. However, the success of the animal experiments in the series of orbital spaceships in 1960 and early 1961 apparently caused the Academicians to take a second look at the expanding new scientific area of bioastronautics. Suddenly a small group of life scientists at the Academy, headed by N. M. Sisakyan (who was then head of the Department of Biological Sciences of the Academy of Sciences USSR), decided that they were missing an important bet. Sisakyan, sometimes alone and sometimes in conjunction with V. V. Parin, V. N. Chernigovskiy, and V. I. Yazdovskiy (who were then the recognized leaders of Soviet bioastronautics), began publishing a series of articles on the biological problems of spaceflight [567, 568, 570, 573, 574].

It is difficult to say whether it was the prestige, or the funds that undoubtedly went along with the work for the space race, but it became quite evident that Sisakyan was determined that the Academy of Sciences USSR should get its fair share of the bioastronautics program. Since both funds and glory were involved, it is interesting to speculate on just how Sisakyan went about taking part of the glory and the funds away from the Academy of Medical Sciences and the Institute of Aviation Medicine, who had performed most of the drudgery and discouraging preliminary work. Perhaps, the prestige of the Academy of Sciences was in itself sufficient to convince the leaders of the Soviet government that the Academy should have part of the program. In any case, the position of the Soviet Air Force specialists at the Scientific Research Institute of Aviation Medicine was apparently quite secure. Consequently, any share of the program that the Academy of Sciences was to get had to be taken away from the Academy of Medical Sciences. There must have been a bitter fight. By early 1962, it was obvious that Sisakyan and the Academy of Sciences had won.

It has been suggested that in order to win this fight, Sisakyan must have obtained the cooperation of the specialists from the Institute of Aviation Medicine, since they had a primary hold on the program. Specialists from the various institutes of the Academy of Medical Sciences (e.g., Professor Parin and his co-workers) could, of course, publish quite freely under their own names and under the names of their institutes. But by this time the research work at the Institute of Aviation Medicine had been classified. It has been suggested that the inducement offered by Sisakyan to the specialists of the Institute of Aviation Medicine was that the assignment of a part of the program to the Academy of Sciences would make it possible for the work of the aviation specialists to be published under the aegis of the Academy of Sciences. Whether this was the inducement that turned the trick or not cannot be substantiated, but whatever quid pro quo was offered, it was quite evident by early 1962 that the Academy of Sciences USSR had officially taken charge of the scientific part of the Soviet bioastronautics program.

To commemorate and consolidate his gains, Sisakyan, with characteristic energy, published the first two volumes of Problems of Space Biology and a monograph on the First Manned Spaceflights. All these publi-

cations were printed under the auspices of the Department of Biological Sciences of the Academy of Sciences USSR. The lists of editors and co-authors of these volumes are very revealing, and the order of appearance of these names should be studied as carefully as the lineup of the Soviet Presidium leaders at the May Day Parade. Leaders of the defeated Academy of Medical Sciences were all but banished from the scene. Professor V. V. Parin, who was then the Director of the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences, had played too prominent a role in Soviet bioastronautics up to that point to be eliminated entirely, but participation by specialists of the Academy of Medical Sciences was kept to a minimum. This was particularly evident in the composition of the Soviet delegation to the International Symposium on Basic Environmental Problems of Man in Space, held in Paris in October, 1962. At this important bioastronautics conference, not a single one of the leaders from the Academy of Medical Sciences was permitted to appear. In their stead, persons like Chernigovskiy (Director of the Institute of Physiology of the Academy of Sciences USSR) and Professor Frank (Director of the Institute of Biophysics of the Academy of Sciences USSR), whose interest in bioastronautics at that time was more or less peripheral, were nonetheless dragged to Paris (not altogether reluctantly, it must be said) to attend and participate in the conference. The composition of this particular delegation should, I suppose, be interpreted as a show of strength on the part of Sisakyan and a demonstration of his victory over Parin's cohorts at the Academy of Medical Sciences. His dominance in the program being assured, Sisakyan has since permitted Professor Parin and other leading figures from the Academy of Medical Sciences to gradually seep back into participation in the Soviet bioastronautics program.

Since 1962, Sisakyan has published a third volume of Problems of Space Biology and a second monograph on manned spaceflight, the latter (entitled The First Group Spaceflight) describing the flights of Vostok-3 and Vostok-4. Professor Parin, however, has had his revenge by publishing Aviation and Space Medicine, a single volume which alone contains almost as many articles as the first three volumes of Problems of Space Biology together.

The general flow of bioastronautics information from the USSR has increased markedly in the last two years. The number of articles in the Biological Series of the News of the Academy of Sciences, and the number of articles in the Bulletin of Experimental Biology and Medicine (published by the Academy of Medical Sciences), has greatly increased. In addition, the Soviets have been proposing an exchange of bioastronautics information between the USSR and the USA. The first proposed this at the meeting of the Working Group on Space Biology during the COSPAR Meeting which took place in Florence, Italy in May, 1964. Since that time several meetings have taken place between Dr. Gazenko and officials from NASA. If an agreement on this exchange is reached, we can anticipate that information from the Soviet Union in the field of bioastronautics will increase several fold.

In closing this introduction, it should be stressed that the pur-

pose of the present report is to identify the various research areas of Soviet bioastronautics and to indicate where and by whom this work is being performed. No attempt will be made to present detailed data of Soviet findings. Nor will the scope of this report permit a detailed account of the role of each Soviet scientist. However, information on individual scientists is available and it is felt that it would be useful to publish a second report using the same set of references, but listing the scientists alphabetically and describing the role, work, and associations of each.

Despite the above limitations, a list of scientific and research organizations active in the Soviet bioastronautics program will be appended to the report, with lists of the names of scientists believed to be associated with those organizations.

TABLE OF BIOMEDICAL SPACEFLIGHTS

Date	Vehicle	Type of Flight	Duration of Weightlessness	Living Organism
1949-1952	Geophysical Rockets	up to 100 km	4 min	14 dogs
1953-1956	Geophysical Rockets	up to 110 km	4 min	12 dogs
1956-1960	Geophysical Rockets with Sealed Cabins	200-212 km	up to 6 min	20 dogs
1958-1959	Geophysical Rockets with Sealed Cabins	450-473 km	up to 10 min	6 dogs
3 Nov 1957	Sputnik-II	orbital	----------	Layka (dog)
19 Aug 1960	2nd Orbital Spaceship	orbital	24 hours	Belka and Strelka (dogs)
1 Dec 1960	3rd Orbital Spaceship	orbital	24 hours	Pchelka and Mushka (dogs)
9 Mar 1961	4th Orbital Spaceship	orbital	1 1/2 hours	Chernushka (dog)
25 Mar 1961	5th Orbital Spaceship	orbital	1 1/2 hours	Zvezdochka (dog)
12 Apr 1961	Vostok-1	orbital	1.1 hours	Yu. A. Gagarin
6 Aug 1961	Vostok-2	orbital	25 hours	G. S. Titov
11 Aug 1962	Vostok-3	orbital	95 hours	A. G. Nikolayev
12 Aug 1962	Vostok-4	orbital	71 hours	P. R. Popovich
12 Jun 1963	Vostok-5	orbital	119 hours	V. F. Bykovskiy
14 Jun 1963	Vostok-6	orbital	71 hours	V. V. Tereshkova [Ref 676]
12 Oct 1964	Voskhod	orbital	24 hours	V. M. Komarov K. P. Feoktistov B. B. Yegorov

Short of an official statement by the Soviet Government, nothing confers official standing in the Soviet bioastronautics program as convincingly as direct participation in scientific spaceflight experiments. This standing is easier to establish for scientists working on the technical level than for administrators who are in charge of various aspects of the manned and animal spaceflight program. But vanity, like murder, will out. The leaders like to have their names appear on official publications dealing with spaceflight. They also like to deliver the keynote addresses at space science conferences, and they accept positions as chairmen at various scientific sessions. Consequently, their names are well known and their functions can be deduced from the titles of the many articles they have published.

N. M. Sisakyan's role as the head of the basic scientific support program for the Soviet spaceflight program is too well known to need any substantiation other than his being the editor-in-chief of Problems of Space Biology. A rapid scanning of the articles published by Yu. M. Volynkin makes it evident that he has an important position in the manned spaceflight program; that he is responsible for physical conditions of spaceflight and their effects on biological objects, including man; and that his duties include search for effective means of protecting living organisms against the injurious effect of various spaceflight factors and the factors produced by the dynamics of rocket flight. This last phrase, which is practically a verbatim excerpt from one of his articles published in the third volume of Problems of Space Biology, could almost stand as a job description defining his role in the Soviet space program [585, 649]. In addition, Yu. M. Volynkin, together with V. I. Yazdovskiy and A. V. Lebedinskiy, is concerned with and responsible for the selection and training of Soviet cosmonauts [383, 642]. V. I. Yazdovskiy, as the "personal physician" to the cosmonauts, is primarily responsible for their fitness and well-being. When cosmonauts are subjected to rigorous training on centrifuges or short-term parabolic flights, Dr. Yazdovskiy is on hand to monitor and control the situation [678, 679]. Lebedinskiy appears to be in direct charge of cosmonaut selection and medical monitoring of cosmonaut training [383].

V. N. Chernigovskiy, as the head of the Department of Physiology of the Academy of Sciences USSR, is the nominal head of all the physiological work being performed by scientists of the Academy of Sciences for the Soviet space program. V. V. Parin, as Director of the Institue of Normal and Pathological Physiology of the Academy of Medical Sciences, plays a similar role in the latter organization. Much of the bioastronautics research performed in the Soviet Union is performed by scientists from his institute [124, 470, 710]. The current role of O. G. Gazenko is somewhat difficult to assess. His current importance in the Soviet bioastronautics program stems from his membership on the Commission for Exploration and Utilization of Space of the Academy of Sciences USSR. In this capacity he acts as the chief Soviet negotiator for exchange of bioastronautics information with the officials of NASA. In addition, he is known to hold a post under Chernigovskiy in the Department of Physiology of the Academy of Sciences. His role in the bio-

astronautics program extends far beyond that, however. As a physiologist, he played an active role in the early animal experiments conducted in the 1950's. Currently, his name appears with many different scientific groups performing experiments in direct support of the spaceflight program [37, 182, 193, 195, 649].

Animal experiments in rockets

Yazdovskiy, Gazenko, and Ye. M. Yuganov were among the leaders who conducted the experiments with animals (dogs, rabbits, rats, mice) in rocket flights to altitudes of 110, 210, 450 km [649]. Yazdovskiy, along with A. V. Pokrovskiy and A. D. Seryapin, was responsible for life support of the animals during flights into the upper layers of the atmosphere [666]. A team consisting of B. G. Bugrov, O. G. Gorlov, A. V. Petrov, A. D. Serov, Ye. M. Yugov, and V. I. Yakovlev had the responsibility for conducting and monitoring experiments on the effects on animals of flights in nonpressurized rocket cabins up to elevations of 110 km [116]. A. M. Galkin, O. G. Gorlov, A. R. Kotova, I. I. Kosov, A. V. Petrov, A. D. Serov, V. N. Chernov, and V. I. Yakovlev apparently had similar responsibility for animal flights up to elevations of 212 km in pressurized cabins [174]. I. I. Kas'yan had the responsibility of monitoring cardiovascular and respiratory reactions of the animals in rocket flights during the 212 km series and the 450 km series. At the time of publication of this information in 1963, Kas'yan was listed as a member of the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR, but there is no reason to assume that the work was performed at this institute [286,287]. Kas'yan together with Ye. M. Yuganov and T. S. L'vova, investigated the morphological and biochemical properties of the peripheral blood of dogs after their flights in rockets]285].

Experiments with the dog Layka

Experiments with the dog Layka performed on Sputnik II (not to be confused with the Second Orbital Spaceship), were performed by a large team which included V. I. Yazdovskiy, V. N. Chernigovskiy, O. G. Gazenko, A. A. Gyurdzhian, A. M. Genin, A. R. Kotovskaya, A. D. Seryapin, I. S. Balakhovskiy, Ye. M. Yuganov, V. N. Chernov, and V. I. Yakovlev [62, 125, 189, 649]. Layka and other dogs were trained for spaceflight under the overall direction of Professor Pokrovskiy (presumably at the Scientifc Research Institute of Aviation Medicine in Moscow) [751]. The actual training appears to have been handled by O. G. Gazenko and V. S. Georgiyevskiy [186]. Gazenko also worked with A. A. Gyurdzhian and G. A. Zakhar'yev on a restraint system for the animals in the sealed cabin and on a sanitary device for collection of body wastes. Gyurdzhian and Gazenko also supervised the placement of sensors for registration of physiological functions [185, 187, and 188]. A. D. Seryapin was responsible for the air regeneration system in the cabin [537],

while I. S. Balakhovskiy, L. I. Karpova, and S. F. Simpura calculated the food and water requirements for dogs in spaceflight and designed feeding devices. It is assumed that they were also responsible for training the animals to use these devices. These devices were used not only for Layka on Sputnik II, but also for Belka and Strelka on the Second Orbital Spaceship [63]. A team consisting of A. A. Gyurdzhian, N. N. Demin, N. V. Korneyeva, T. S. L'vova, L. T. Tutochkina, M. S. Uspenskaya, and T. A. Fedorova was responsible for monitoring the metabolism of the animals after their return from spaceflight. This team, which worked with Layka, had also worked on experiments with dogs in ballistic rockets [247].

Experiments on the Orbital Spaceships and the Vostoks

In the experiments following Layka's flight, many scientific teams conducted animal and plant studies on the flights of the orbital spaceships and the Vostok series ships. V. I. Yazdovskiy headed a team which included G. V. Altukhov, V. Ye. Belay, A. D. Yegorov, and V. I. Kopanev, whose duty was to monitor emotional strain on the cosmonauts during spaceflight [679]. Another team, consisting of V. I. Yazdovskiy, I. I. Bryanov, L. I. Kakurin, Yu. V. Krylov, and M. A. Cherepakhin, studied sensory motor coordination under conditions of prolonged weightlessness during actual spaceflight [673]. A team consisting of L. D. Luk'yanova, N. N. Livshits, Z. I. Apanasenko, and M. A. Kuznetsova made a study of the higher nervous activity of white rats flown in the Second Orbital Spaceship. This group was particularly interested in the delayed effects of spaceflight on higher nervous activity [392, 393, 394]. Z. I. Apanasenko, working together with M. A. Kuznetsova at the Institute of Biophysics of the Academy of Sciences USSR, studied the delayed effect of spaceflight on the vestibular and flexor reflexes of guinea pigs [43].

The effect of factors of spaceflight on immunological reactions of the organism was studied by O. G. Alekseyeva and A. P. Volkova [20, 21]. V. V. Yakolev studied the effect of spaceflight on peripheral circulation of blood in dogs [658, 659]. M. A. Arsen'yeva, working with V. V. Antipov, V. G. Petrukhin, T. S. L'vova, N. N. Orlova, S. S. Il'ina, L. A. Kabanova, and E. S. Kalyayeva, studied the effect of spaceflight factors on the hematopoietic organs of mice who had been flown on the Second, Fourth, and Fifth Orbital Spaceships [49, 51, 52]. Several research groups have concerned themselves with effects of spaceflight and of training on the blood and urine content of animals and cosmonauts. Thus, a team consisting of A. A. Gyurdzhian , N. N. Demin, L. T. Tutochkina, M. S. Uspenskaya, and T. A. Fedorova, did biochemical research of the blood and urine of animals which had completed flights in space vehicles [250]. V. S. Shashkov, working together with V. V. Antipov, M. O. Raushenbakh, G. A. Chernov, and V. A. Maslennikova, studied the influence of spaceflight factors on the serotonine level in the blood of animals which had been subjected to spaceflight [546]. A third team, consisting of T. A. Fedorova, L. T. Tutochkina, M. S. Uspenskaya, M. M. Skurikhina, and Ye. A. Fedorov, studied the blood and urine composition of cosmonauts before and after training, and before and after spaceflight [165, 166].

The genetic effects of spaceflights were also investigated by several teams. Most of this work was performed at the Institute of Biophysics of the Academy of Sciences USSR, under the direction of Ya. L. Glembotskiy. One such team, consisting of Ya. L. Glembotskiy, E. A. Abeleva, Yu. A. Lapkin, and G. P. Parfenov, investigated the effects of spaceflight factors on the frequency of appearance of recessive lethal mutations in Drosophila melanogaster [208, 211, 213, 214]. G. P. Parfenov, also working with Drosophila melanogaster, studied the occurrence of dominant lethal mutations resulting from exposure to spaceflight on orbital spaceships [457, 458]. More recently, still working with Drosophila melanogaster, Parfenov has investigated the development of the organism under weightless conditions and the reasons for gamete lethality in Drosophila which had been exposed to spaceflight on Vostok-3 and Vostok-4 [459, 460]. N. P. Dubinin and O. L. Kanavets have been studying the effect of spaceflight factors on nonseparation of chromosomes in Drosophila [161]. E. A. Abeleva, G. P. Parfenov, and Yu. A. Lapkin have also studied crossovers in Drosophila males as a result of spaceflight factors [2]. M. A. Arsen'yeva, Yu. S. Demin, G. L. Pokrovskaya, L. A. Belyayeva, L. I. Gavrilova, and A. V. Golovkina have been studying the effect of spaceflight factors on hereditary structures in mammals [50].

Plants rather than animals have been the subjects of many of the more recent spaceflight experiments. Thus, Glembotskiy has extended his genetic studies to cover the influence of spaceflight factors on the heredity and development of actinomycetes and higher plants. He performed this work, not with the group which had worked with him on Drosophila, but with a team consisting of A. A. Prokof'yeva-Bel'govskaya, Z. B. Shamina, S. Yu. Gol'dat, V. S. Khvostova, S. A. Valeva, N. S. Eyges, and L. V. Nevzgodina [209, 212]. V. V. Khvostova, working with A. A. Prokof'yeva-Bel'govskaya, B. N. Sidorov, and N. N. Sokolov, has also investigated the effect of spaceflight factors on the seeds of higher plants and actinomycetes carried on the 2nd, 4th, and 5th Orbital Spaceships and Vostok-1 and Vostok-2 [304]. Working with three other scientists, S. A. Gostimskiy, V. S. Mozhayeva, and L. V. Nevzgodina, Khvostova made a study of the influence of spaceflight conditions on the chromosomes of the primary roots of pea and wheat sprouts [305]. B. N. Sidorov and N. N. Sokolov have been studying the influence of spaceflight conditions on the seeds of Allium fistulosum and Nigella damascena [552, 553]. A team consisting of N. L. Delone, P. R. Popovich, V. V. Antipov, and V. G. Vysotskiy, has made a study of the effects of spaceflight on the mitotic mechanism of Tradescantia paludosa microspores flown on Vostok-3 and Vostok-4 [142, 143, 144]. Delone, with a slightly different group which included V. F. Bykovskiy, V. V. Antipov, G. P. Parfenov, V. G. Vysotskiy, and N. A. Rudneva, continued to study the effects of spaceflight on Tradescantia microspores on Vostok-5 and Vostok-6 [145]. Still another team, consisting of L. K. Gordon, N. L. Delone, V. V. Antipov, and V. G. Vysotskiy, has studied the effects of spaceflight conditions on seeds of wheat, lettuce, beans, and pine which had been carried on Vostok-3 [229].

Unicellular algae, yeast, and microorganisms were also carried in these spaceflight experiments. V. Ye. Semenenko and M. G. Vladimirova, working under the direction of N. N. Nichiporovich, and with A. A. Gyurdzhian acting as consultant, studied the influence of spaceflight conditions on the preservation of the vitality of chlorella cultures [526, 529, 530]. These experi-

ments, which were carried out at the Institute of Plant Physiology imeni K. A. Timiryazev of the Academy of Sciences USSR, will be described in greater detail in another section of this report. A team consisting of N. N. Kovyazin, A. A. Lukin, and G. P. Parfenov, studied the effects of spaceflight on haploid and diploid yeasts [355, 356]. N. N. Klemparskaya studied the effect of spaceflight conditions on the association of intestinal bacteria [314]. Other experiments with microorganisms, conducted by the large teams headed by N. N. Zhukov-Verezhnikov, will be described in the section of this report devoted to space microbiology.

SPACE MICROBIOLOGY

The program of "cosmic" (i.e., space) microbiology in the USSR is handled almost exclusively by a large team directed by N. N. Zhukov-Verezhnikov, who is Head of the Department of Immunology of the Institute of Experimental Biology of the Academy of Medical Sciences USSR [720, 721, 726]. This team includes the following personnel:

I. N. Mayskiy

Ye. D. Aniskin

V. V. Antipov

N. S. Arten'yeva

Ye. A. Buyko

K. G. Chamova

N. N. Dobrov

G. I. Fedorova

A. A. Gyurdzhian

M. M. Kapichnikov

N. N. Klemparskaya

V. Yu. Klimov

P. A. Konstantinov

V. Ya. Kop'yev

V. A. Kozlov

B. A. Mishchenko

N. P. Nefed'yeva

S. N. Novikov

I. S. Novikova

V. V. Pantyukhova

G. P. Parfenov

A. P. Pekhov

R. V. Petrov

I. I. Podoplelov

N. I. Rybako

K. D. Rybakova

P. P. Saksonov

R. I. Shupik

N. G. Sushko

G. P. Tribulev

Ye. P. Ugryumov

I. N. Vinogradova

N. M. Volkov

V. G. Vysotskiy

V. I. Yazdovskiy

Ye. V. Yudin

A. F. Zakharov

[References: 722, 725, 726, 727, 728, 729, 730].

Most of Zhukov-Verezhnikov's associates in space microbiology are from his own Institute of Experimental Biology. Top-echelon personnel on this team include I. N. Mayskiy (Zhukov-Verezhnikov's Chief, and Director of the Institute of Experimental Biology), A. P. Pekhov, and N. P. Nefed'yeva [414, 726]. It is interesting to note that this space microbiology team also includes Yazdovskiy, Gyurdzhian, and Antipov. It is definitely known that these people are not members of the staff of the Institute of Experimental Biology. It should be assumed, therfore, that they participate in this program as consultants, since all three stand in very close relationship to direct experiments in spaceflight. Their presence on Zhukov-Verezhnikov's space microbiology team will become almost self-explanatory as we examine the mission of that team in the Soviet space effort [727].

Microorganisms as sensors

The mission of the Institute of Experimental Biology in the Soviet space program has been the utilization of microorganisms for testing the effects of spaceflight, particularly the effects of radiation encountered in space along trajectories selected for future manned spaceflights [720]. The basic problem was to find a microorganism which was as resistant as possible to the effects of vibration and other flight dynamic factors of spaceflight, but sensitive to radiation. To this end, various microorganisms were carried along on the orbital spaceships which preceded the Vostok series. Two strains of E. coli, Streptococcus albus, and Aerogenes 1321, were tested. Lysogenic bacteria proved to be the most sensitive of the organisms tested owing to their characteristic of producing phage in proportion to the size of the radiation dose. Clostridium butyricum was used to flight-test the automatic inflight recording and reporting equipment for monitoring the viability of the microorganisms. Radio-resistant bacterial phage strains T2 and 1321 were included to rule out any possible unknown factors in the space environment which might have destroyed the more sensitive bacteria [720, 721]. Human and rabbit skin cultures were also flown on spaceflight experiments and afterwards regrafted to the original donors. It was found that the skin in all cases retained its viability after spaceflight [722].

This large order was simplified by subdividing it into a number of specific tasks, which were then assigned to individual groups of researchers. Thus, a team from Zhukov-Verezhnikov's laboratories and consisting of I. I. Podoplelov, A. F. Zakharov, and Ye. P. Ugryumov made a study of the conditions required to culture human tissue on glass so that it could be sent into space [727]. Another team, headed by M. M. Kapichnikov and including N.I. Rybakov, N. G. Sushko, and N. N. Sorokina (biologists), and A.A. Vishnevskiy, M. I. Dolgina, O. P. Nikitina, and M. I. Shrayber (surgeons), worked directly on experiments which involved sending skin grafts into space [727]. A. P. Pekhov directed a team consisting of N. I. Rybakov, V. A. Mishchenko, and Ye. A. Buyko on the problem of whether or not the lysogenic phenomenon can be regarded as a genetic phenomenon, and whether or not it is possible to distinguish spontaneously formed phage particles from those formed as a

result of exposure to radiation in space. The E. coli K-12 strain of lysogenic bacteria was used as the experimental material in this work [727]. N. N. Klemparskaya performed preliminary experiments with E. coli which had been subjected to spaceflight factors [727]. More extensive experiments with auxotrophic mutations of bacteria which had been subjected to spaceflight factors were carried out by a larger team headed by A. P. Pekhov and which included N. N. Klemparskaya, R. V. Petrov, I. S. Novikova, I. N. Vinogradova, K. D. Rybakova, G. I. Fedorova, and B. A. Mishchenko [727].

The single most important achievement of Zhukov-Verezhnikov's space biology team was the design and construction of the AMN-1 biosensor element which makes it possible to detect radiation danger to living organisms on spaceflights of long duration, such as flights to other planets. This team (which included scientists from other institutes and agencies in addition to some from the Institute of Experimental Biology) was headed by V. I. Yazdovskiy and included A. P. Pekhov, N. I. Rybakov, N. P. Nefed'yeva, I. P. Smirnov, A. I. Bogdanov, S. V. Sobolevskiy, A. A. Gyurdzhian, I. S. Novikova, V. V. Antipov, and Yu. G. Merkushkin [727]. Before the AMN-1 biosensor could be constructed, a suitable organism had to be found. In this search N. P. Nefed'yeva directed a team of microbiologists, who finally selected Clostridium butyricum as the most suitable organism [727]. The AMN-1 biosensor was built by I. P. Smirnov, A. I. Bogdanov, and S. V. Sobolevskiy [722].

Further investigation of the lysogenic phenomenon

Since 1962, the lysogenic phenomenon has remained one of the major problems of space microbiology. In this area, A. P. Pekhov has been working on the development of a method for preparing ultra-thin cross sections of bacteria in order to study the lysogenic phenomenon intracellularly [475]. The next stage of research, conducted by A. P. Pekhov and B. A. Mishchenko, included electron microscopy of the development of lysogenic phages in the cells of the indicator strain [478]. Simultaneously, Zhukov-Verezhnikov and his associates (Mayskiy, Pekhov, Tribulev, Rybakov, and Rybakova) have been studying the E. coli K-12 cultures which had been carried on Vostok-2. N. N. Klemparskaya, participating in this work, isolated a variety which showed signs of dissociation. From this variety, 24 changed types have been isolated; these were originally considered to be simple auxotrophic mutants, since they had lost the ability to synthesize certain amino acids. Nineteen methionine-dependent mutants lost their ability to utilize lactose, glucose, galactose, mannite, etc., and some became hydroxide producers. These properties indicate profound changes, including pathological ones [726].

This line of research has led A. P. Pekhov, assisted by A. A. Abidov, Ye. V. Yudin, T. A. Besova, and M. S. Sychkov, to study the genetic recombinations of bacteria and the effect of high-energy protons on colon bacilli. Irradiation with 660-Mev protons was performed at the United Institute of Nuclear Studies in Dubna [476, 477, 479]. These synchrocyclotron

experiments have shown that the reaction of E. coli K-12 (λ) bacteria to protons and neutrons is similar to that produced by radiation in space, and that phage production is proportional to the irradiation dose. Other experiments have shown that when lysogenic bacteria are subjected to vibration they do not produce phage particles. These experiments were carried out under Zhukov-Verezhnikov, by a modified team including:

V. I. Yazdovskiy	N. A. Artem'yev
I. N. Mayskiy	V. A. Kozlov
G. P. Tribulev	B. A. Mishchenko
A. P. Pekhov	Ye. V. Yudin
P. P. Saksonov	K. D. Rybakova
N. I. Rybakov	Ye. D. Aniskin
V. V. Antipov	

[Ref. 730]

It has been established that this lysogenic system is highly sensitve to radiation but stable against other spaceflight stress factors. This has led to the decision that in the immediate future it will be necessary to couple this biological radiation sensor with an automatic system which will permit registration and telemetry of information from space to earth. The principles for creating such an automatic telemetry system have already been worked out, making it possible to begin construction of experimental equipment [730]. In the course of this research, Zhukov-Verezhnikov and his colleagues discovered that this lysogenic system can also be used for testing the effectiveness of antiradiation drugs. Recent experiments with β-mercaptopropylamine have shown that phage production can be reduced by the use of such drugs. If it turns out that the phage production induced by heavy particles can also be reduced by antiradiation drugs, then the lysogenic system could be used for fast primary selections of new means of chemical protection against radiation [730]. There are indications that this antiradiation drug research is already being carried on by means of this lysogenic system.

In addition to the work being done by Zhukov-Verezhnikov's team, a number of individual scientists appear to be working on related aspects of the lysogenic and phage problem. Thus, A. S. Krivitskiy and N. Ya. Solov'yeva are working on the mutagenic effect of ultraviolet rays on extracellular phage [360]. Another researcher, G. Ye. Fradkin, has worked on the reproduction of phage in irradiated unvital cells using E. coli variety (B) [170]. Elsewhere, a team consisting of V. N. Chernov, V. M. Bereznikov, V. P. Drevush, and A. N. Kolbasov have developed an automatic device for registering the growth of microorganisms. This device, which is based on turbidity, appears to be intended for ground laboratory use. Whether this system can be modified for use on spacecraft seems doubtful [127].

In retrospect, it becomes obvious that the role of space microbiology in the Soviet Union is really a part of space-oriented radiobiology which is concerned with radiation safety in spaceflight. The development of the AMN-1 bioelement and the studies of the radiation-sensitive lysogenic microbiological system is not only the chief achievement of space microbiologists in the USSR, but remains their primary problem.

EXOBIOLOGY

Exobiology is the least developed area of the space-oriented life sciences. It is almost peripheral to the main Soviet bioastronautics effort. However, its official existence cannot be doubted, since papers on exobiology are presented each year at the COSPAR meeting.

Strictly speaking, exobiology is concerned with the study of extra-terrestrial life. But since space exploration has not yet reached the point where man has encountered extra-terrestrial organisms, the current program of exobiology is concerned with methods and devices for detection of extra-terrestrial life in space, with the sterilization of space vehicles and space probes (to prevent contamination of other planets with terrestrial organisms), and with the tolerance of known living organisms to extreme environments such as may be encountered in space or on other planets.

Modern exobiology in the USSR may be said to have gotten its start in the late 1940's when the Soviet astronomer, G. A. Tikhov, founded the new science of astrobiology, or more correctly, astrobotany [618, 619]. Tikhov's studies were based largely on the similarity between the spectral absorption of plants at high altitudes and spectra obtained from certain parts of Mars. The current leaders in Soviet exobiology are: A. A. Imshenetskiy, Director of the Institute of Microbiology of the Academy of Sciences USSR; A. I. Oparin, Director of the Institute of Biochemistry of the Academy of Sciences USSR; and L. K. Lozina-Lozinskiy, of the Institute of Cytology of the Academy of Sciences USSR. [389, 742, 744]

Detection of extra-terrestrial life

A. I. Oparin is interested in extra-terrestrial life as it might be found on other planets largely in order to obtain additional data on the evolutionary aspects of how life arose on Earth [452]. The evolutionary approach is also used at Imshenetskiy's Institute of Microbiology, where it is felt that the evolution of metabolic functions in microorganisms bears a close relationship to the evolution of physicochemical conditions on Earth. A paper on this subject was presented by A. I. Zhukova (of the Institute of Microbiology) at the 1963 COSPAR meeting in Warsaw, Poland [717]. A more direct approach is taken by Imshenetskiy himself, who states that the most pressing problem facing Soviet exobiologists is the design and construction of small, lightweight equipment for detecting life in space and on nearby planets. His researchers at the Institute of Microbiology have designated the three groups of microorganisms that it will have to be detected: heterotrophic, hemoautotrophic, and photosynthesizing bacteria. The actual construction of such devices is an engineering and instrument-building problem, and it is to be assumed that work in this direction is progressing with the

cooperative participation of members of the Institute of Microbiology and equipment builders in the USSR [256, 257].

Sterilization of space vehicles

In the meantime, Imshenetskiy has been saddled with a more immediate and more practical problem, that of sterilization of space vehicles to prevent contamination of planetary surfaces [255]. The study of this problem has naturally led Imshenetskiy and his co-workers to study the ability of terrestrial microorganisms to withstand ultraviolet radiation and ultra-high vacuums, such as are encountered in space. Because of the technical difficulty of exposing living organisms on the exterior of spacecraft, microorganisms are being exposed to simulated space conditions in the laboratory. These experiments have determined that UV radiation is the most effective space environment factor thus far found for sterilization, but that since the penetration capacity of UV radiation is low, insignificant amounts of organic or mineral overlay (i.e., space dust) may protect bacterial cells. On the other hand, it was found that various microorganisms could be exposed to vacuums of the order of 10^{-8} to 10^{-10} mm Hg at a temperature of -23°C without affecting their viability.[164, 255, 258, 259]

Meteor microbiology

When, in June of 1962, reports appeared in Soviet papers that two Turkmen medical scientists, Bayryyev and Mamedov, had discovered extra-terrestrial organisms on the inside of meteors, the Institute of Microbiology investigated. Professor Imshenetskiy, in a joint statement with Academicians Oparin and Fesenko, stated that there were no grounds for assuming that the thermophilic bacteria found by the Turkmen scientists were of extra-terrestrial origin. A special study was performed by S. Abyzov and A. Imshenetskiy which demonstrated that rocks and meteorites are easily penetrated and contaminated by various soil microorganisms, with the result that only meteorites which are removed from soil immediately upon their arrival on Earth can be considered suitable for investigation of the possible presence of extra-terrestrial life. [3, 742, 753, 765]

Adaptation to extreme environments

Another phase of the program of exobiology is concerned with tolerance of terrestrial organisms to nonterrestrial environments. Thus, A. I. Zhukova and I. I. Kondrat'yev, in a paper presented at the 1964 COSPAR Con-

ference in Florence, Italy, describe a climate chamber which was designed at the Institute of Microbiology in order to investigate the effects of Martian environment on terrestrial microorganisms and to determine what types of microorganisms are most likely to be found on Mars if this form of life exists there [718]. A more extensive program on adaptation to extreme environments is being carried out at the Institute of Cytology of the Academy of Sciences USSR, and the Institute of Physiology imeni Pavlov, also of the Academy of Sciences USSR, under the direction of L. K. Lozina-Lozinskiy. Most of these studies are concerned with adaptation to low and ultra-low temperatures, rarefied atmospheres, and various types of radiation. Under his guidance, N. B. Il'inskaya worked on the effects of low temperatures on insects; L. G. Vol'fenzon and N. V. Zander investigated epithelial muscle cells of various rodents; V. M. Rumyantseva studied the ability of yeast to withstand ultra-low temperatures; K. A. Samoylova and V. L. Levina studied the effects of UV rays on paramecia and the epithelium of pearl oysters; and I. A. Mikhal'chenko studied the comparative resistance of insects to oxygen deficit and low barometric pressure [389, 390, 391, 744]. Experiments with caterpillars have shown that insects can withstand a temperature of -178°C for prolonged periods of time [744]. Experiments conducted at the Artificial Climate Station of the Academy of Sciences USSR, have shown that some of the higher plants, such as the black currant, can resist temperatures down to -253°C, provided they are gradually acclimatized to low temperatures. Unicellular protozoa and spores of bacteria and fungi can survive temperatures close to -273°C. The spores of some bacteria and fungi can also endure temperatures up to 170°C and pressures of 17,600 atm, while the seeds of higher plants such as pine and oak remain viable after exposure to temperatures of 120°C. Nematodes have withstood pressures of 800 atm [762]. G. T. Voronov of the Institute of Microbiology, has studied the effects of low temperatures on the structure of enzymes and has determined that the adaptation of living organisms to low temperatures is associated with structural alterations in their proteins and enzymes [653]. This interest in the ability of living organisms to adapt to extreme temperatures resulted in a symposium on cytoecology jointly sponsored by the Academy of Sciences USSR and UNESCO, which was held in Leningrad from 31 May to 5 June 1963. Most of the papers given at this symposium dealt with the role of cellular reactions in the adaptation of multicellular organisms to the temperature of the envrionment. The symposium served to identify the chief problem areas of cytoecology [715].

Studies on acclimatization and adaptation to cold environments in man cannot, properly speaking, be considered part of the program of exobiology. But it is interesting to note that the studies on this subject performed by I. I. Tikhomirov, of the Department of Physiology of the Moscow Medical Institute of Stomatology, should have been submitted for publication by V. V. Parin and A. V. Lebedinskiy, both of whom play prominent roles in the Soviet space program [615, 616, 617]. A similar relationship to the space program cannot be established for the studies on acclimatization to cold factors carried out by I. S. Kandror of the Physiological Laboratory of the Moscow Institute of Hygiene [278] or for Yu. M. Gubachev's study of immunological reactions of the organism to arctic conditions [239], but they may nonetheless have a general bearing on spaceflight and particular relevance to colonization of the Moon and Mars.

Studies of plants at high altitudes

The Soviet space program includes studies of plants at high altitudes conducted at the Pamir Botanical Gardens by a number of Soviet scientific teams. A. A. Shakhov and V. S. Khazanov, of the Institute of Plant Physiology imeni Timiryazev of the Academy of Sciences USSR, together with L. F. Ostapovich, of the Pamir Botanical Garden of the Tadzhik Academy of Sciences, have studied the spectral properties of plants cultivated in the Pamirs [540, 541]. Much of their work was concerned with photoadaptation and photoreactivation, which enabled the plants to withstand the intense radiation of near-space [542]. Yu. L. Sokolov and A. V. Gurskiy, also working with Ostapovich, have also been concerned with photoreactivation and photoadaptation, in order to determine the effects of extra-terrestrial radiation on plants which may have to be grown in spaceships [595, 596]. T. A. Glagoleva has studied photosynthetic processes in plants at the Pamir Biological Station, 3860 meters above sea level, and at the Tsirk Zora Station, 4780 meters above sea level [206]. Similar work is being conducted on the southern slope of Mount Aragats in Armenia by staff members of the Alpine Biological Station of the Botanical Institute of the Armenian Academy of Sciences [515]. All of these studies follow the pioneer work done by a team consisting of L. P. Breslavets, M. N. Berezina, G. I. Shibrya, and M. L. Romanchikova, of the Institute of Biophysics of the Academy of Sciences USSR [112]. In 1963, Breslavets, who was then still at the Institute of Biophysics, was studying the modern concept of the origin of plastids. It is difficult to determine whether these high altitude studies of plants are funded in whole or in part by monies allocated for Soviet space studies, but there can be little doubt that the scientists working on these teams either consider themselves part of the space program or are making an effort to get in on the space act. The publication of these articles in collections such as Problems of Space Biology indicates that these studies are sufficiently space-oriented to be considered acceptable by the leaders of the Soviet bioastronautics movement who compose the editorial board of the series.

SPACE-ORIENTED RADIOBIOLOGY

The overwhelming majority of the work published on radiobiology is not space-oriented; close to ninety percent of the articles in journals such as Radiobiologiya (Radiobiology) are on clincially or industrially-oriented radiobiology. In this report we will be concerned only with space-oriented radiobiology, i.e., studies dealing with the types of radiation found in space and with radiation encountered during spaceflight experiments, and such ground experiments with high-energy protons as can definitely be related to the space program.

Leaders in space-oriented radiobiology

The Soviet leaders in space-oriented radiobiology are: Yu. M. Volynkin, A. V. Lebedinskiy, V. V. Antipov, A. A. Gyurdzhian, and P. P. Saksonov. The most important of these is probably Yu. M. Volynkin, since he appears to have primary responsibility for the major radiobiological problem, that of radiation safety in spaceflight [644, 645, 646, 647, 648, 649, 650]. The two names that appear most frequently with Volynkin's on articles concerning radiation safety are those of P. P. Saksonov and V. V. Antipov. When an article deals directly with the radiation safety measures taken to protect Soviet cosmonauts, two additional names appear, those of M. D. Nikitin and N. N. Dobrov [648, 650]. A. V. Lebedinskiy is primarily concerned with the effects of radiation on the central nervous system [379, 380]. V. V. Antipov and P. P. Saksonov appear to be the two men in the Soviet spaceflight program who work with everyone in the field. The inference drawn from this is that they are official consultants for the spaceflight program. Both are radiobiologists.

Thus, Antipov worked with the team headed by M. A. Arsen'yeva on changes produced in the hematopoietic organs of animals subjected to orbital spaceflight [49, 51, 52]. He acted as consultant to the team headed by N. L. Delone on biological experiments carried out on spaceships Vostok-3, Vostok-4, Vostok-5, and Vostok-6 [144, 145]. He was a co-author with V. S. Shashkov when the latter worked on the effect of spaceflight factors on the serotonin level of the blood [546], and he acted as consultant on a large number of studies and experiments performed and published by N. N. Zhukov-Verezhnikov [725, 727, 728, 729, 730].

Saksonov's role as a consultant seems to be more limited. Almost invariably he works on some aspect of radiation safety in spaceflight. The fact that his name appears together with that of Volynkin on the one hand and Sisakyan on the other, shows that he is one of the more important radiobiologists in the space program [586, 589, 645, 648, 649]. He, too, has participated as consultant in certain experiments performed by N. N. Zhukov-Verezhnikov [728, 729, 730].

A. A. Gyurdzhian is, apparently, also a consultant on radiobiological problems related to spaceflight. However, unlike Antipov and Saksonov, who only participate in experiments which deal with radiobiology, Gyurdzhian appears to be equally at home with experiments concerning acceleration and life-support systems [64, 185, 187, 188, 248, 249, 251, 722]. He has also worked with Zhukov-Verezhnikov on experiments in space microbiology [722, 725, 727]. The name of N. M. Sisakyan occasionally appears at the head of articles dealing with problems of space-oriented radiobiology, but this is due largely to Sisakyan's desire to keep his name in print in association with one of the crucial problems of spaceflight [589].

Radiation safety in spaceflight

Yu. M. Volynkin's dominant role in the problem of radiation safety in spaceflight has already been mentioned. When one adds to this the fact that he is a Lieutenant General of the Medical Service [652], that he is the principle author of The First Manned Spaceflights [575] and The First Group Spaceflight [584], and that his name appears immediately after that of Sisakyan on the editorial board of volumes 2 and 3 of Problems of Space Biology [581, 585], it becomes almost self-evident that Yu. M. Volynkin is in official charge of radiation safety for the Soviet manned spaceflight program.

On a more technical level, the names of I. A. Savenko, N. F. Pisarenko, and P. I. Shavrin appear on articles dealing with radiation hazards in spaceflight [519, 523]. The members of this team, headed by Savenko are evidently not so much concerned with radiobiology as with radiation conditions encountered in spaceflight. Their papers deal with the Van Allen Belts and solar flares. If one had to hazard a guess as to their official position within the spaceflight program, one would say that they are responsible for determining whether or not the radiation conditions obtaining at any given moment make spaceflight safe or feasible. A. V. Lebedinskiy and V. V. Antipov are also interested in problems of radiation danger in spaceflight, but this interest is oriented more towards dosimetry and the determination of the RBE of radiation in spaceflight [39, 381]. It is quite probable that Lieutenant General Volynkin's responsibilities extend to radiation safety procedures, dosimetry, and monitoring on the manned spaceflights, for he is quite obviously the official spokesman on these matters [740]. On a technical level, three teams are responsible for problems of dosimetry and radiation monitoring during spaceflight. The first of these teams is headed by I. A. Savenko and includes N. F. Pisarenko, P. I. Shavrin, V. Ye. Nesterov, M. V. Tel'tsov, and V. N. Yerofeyeva [518, 520, 521, 522]. There can be no question that this team is responsible for the physical aspects of dosimetric measurements on Soviet spacecraft, since their articles appear in the strictly official publications of the Soviet spaceflight program, namely, Iskusstvennyye sputniki Zemli (Artificial Earth Satellites) [518] and Kosmicheskiye issledovaniya (Space Research) [520, 521, 522]. The determination of radiation dose

inside the spaceship has also been dealt with by a team consisting of V. N. Lebedev, V. S. Morozov, G. F. Murin, M. D. Nikitin, and M. I. Salatskaya [377]. The specific problem of the determination of secondary or induced radiation inside the spaceship has been studied by a team consisting of V. V. Matveyev and A. D. Sokolov [412, 413]. These last two teams must obviously also have official standing in the program, since their reports are also published in the official spaceflight publications mentioned above.

The monitoring and dosimetry of tissue doses absorbed by the cosmonauts in flight is the responsibility of still another team which includes I. A. Bochvar, A. A. Vasil'yeva, I. B. Keirim-Markus, Ye. Ye. Kovalev, N. A. Sergeyeva, and L. N. Uspenskiy [96, 292, 293]. Because Iskusstvennyye sputniki Zemli and Kosmicheskiye issledovaniya follow a policy of publishing the names of authors in strictly alphabetical order, it is not possible to determine who is the leader of this team.

Radioprotective agents

The problem of protection against radiation by means of antiradiation drugs has been one of the major concerns of radiobiologists for a number of years. V. V. Antipov and I. G. Krasnykh worked on this problem in the late 1950's, when they tested the protective properties of para-aminopropiophenone and para-aminobuterophenone [36]. Another team, consisting of S. Ya. Arbusov and Ye. M. Anosova, were working as long ago as 1957 on the radioprotective properties of phenatin at the Military Academy imeni S. M. Kirov in Leningrad [45]. Study of the effects of antiradiation agents is being continued even today at the Military Academy imeni S. M. Kirov, where V. I. Kuznetsov (not to be confused with A. Ye Kuznetsov) and M. S. Kushakovskiy are working on the problem [374]. N. N. Klemparskaya appears to be working on this problem also, but her approach is oriented to the phenomenon of immunization, and her work is concerned largely with intestinal bacteria. There can be no doubt, however, about her direct relationship with spaceflight experiments, since her work was published in Iskusstvennyye sputniki Zemli [314].

A somewhat different approach to the problem of chemical protection against radiation is used by S. P. Yarmonenko, who, with a large team consisting of E. B. Kurlandskaya, G. A. Avrunina, R. D. Govorun, Ye. S. Gaydova, R. L. Orlyanskaya, G. F. Palyga, V. L. Ponomareva, V. I. Fedorova, N. L. Shmakova, and V. S. Shashkov, has been analyzing the effect of radioprotective agents against whole body irradiation with high-energy protons [660, 661, 662, 663, 664]. Most of this work has been performed in the Radiotoxicology Laboratory (headed by E. B. Kurlyandskaya) at the Institute of Industrial Hygiene and Occupational Diseases or the Academy of Medical Sciences USSR, in Moscow [660, 663]. Although the work is performed in ground laboratories, the use of 660-Mev protons, which have an RBE close to that of radiation encountered in space, makes this work space-oriented radiobiology. That this work is related to the space program is evident from its publication in Problems in Space Biology [661].

Effects of high-energy protons

E. B. Kurlyandskaya, together with G. A. Avrunina, R. D. Govorun, V. L. Ponomareva, V. I. Fedorova, and B. I. Yanovskaya, has been exploring the RBE of 660-Mev protons for a number of years at the Radiotoxicology Laboratory of the Institute of Industrial Hygiene and Occupational Diseases of the Academy of Medical Sciences [365]. Another team, consisting of I. A. Rapoport, S. P. Yarmonenko, and G. A. Avrunina, has been studying the effect of high-energy protons on the frequency of occurrence of mutations [500]. Yu. I. Moskalev and I. K. Petrovich have been exploring the effects of 500-Mev proton injuries [432]. In all of these experiments, exposures to protons with energies from 120 to 660 Mev were made with the synchrocyclotron of the Joint Institute of Nuclear Research in Dubna [365, 517]. Still other experiments simulating the kinds of radiation found in space were performed by I. A. Rapoport and A. V. Miller, who studied the mutogenic activity of antiparticles, using Cu^{62} as a positron source and Cu^{64} as a positron and electron source. This rather unusual experiment showed that the genetic effects induced by positrons (recessive lethal mutations, fragmentations of the sex chromosomes, and nondisjunction of microchromosomes) do not differ from those produced by exposure to conventional particles [499].

Genetic effects of radiation

Work on the genetic effects of radiation is concentrated in the Institute of Biophysics of the Academy of Sciences USSR. A team headed by M. I. Arsen'yeva and working in the Radiation Genetics Laboratory of this institute has been exploring the cytological radiosensitivity of germ cells of various mammals [53]. Another team from this institute, consisting of N. P. Dubinin, Yu. Ya. Kerkis, and L. I. Lebedeva, has been working on the effects of small doses of radiation on chromosomal rearrangement in the cells in human embryonic tissue cultures [162]. Direct spaceflight experiments have been conducted by a number of teams at the Institute of Biophysics under the general direction of Ya. L. Glembotskiy [210]. Most of Glembotskiy's work deals directly with spaceflight effects. Consequently, his work must be regarded as dealing with the combined effects of spaceflight factors, rather than with the effects of radiation alone. Most of his experiments have been performed in collaboration with E. A. Abeleva, Yu. A. Lapkin, and G. P. Parfenov using Drosophila melanogaster as the experimental object [208, 210, 211, 213, 214]. Without exception, these experiments were concerned with sex-linked recessive lethal mutations induced by spaceflight factors. In the most recent of these experiments, the team was assisted by Ye. M. Kamshilova [214]. With another team, consisting of A. A. Prokof'yeva-Bel'govskaya, Z. B. Shamina, S. Yu. Gol'dat, V. V. Khvostova, S. A. Valeva, N. S. Eyges, and L. V. Nevzgodina, Ya. L. Glembotskiy has performed experiments on the effect of spaceflight factors on the heredity and development of actinomycetes and higher plants [209, 212].

Other radiation studies

Two researchers, A. V. Sevan'kayev and A. A. Sveshnikov, have been exploring the effects of radiation on the vestibular analyzer. This work, which was performed with the aid of a rotating device, has shown that small doses of radiation (50 to 100 r) tend to increase the excitability of the vestibular analyzer, while doses greater than 200 r decrease the excitability of the labyrinth. Higher doses lead to considerable inhibition of the function of the vestibular mechanism [538, 605, 606].

Problems of space-oriented radiobiology also include the biological effects of solar radiation at high altitudes and the edge of space. This type of effect is primarily interesting to botanists who are contemplating taking plants on spaceflights for the purpose of regenerating air and producing food. These experiments will be dealt with in the section on Chlorella and higher plants. However, experiments on the effects of cosmic and solar radiation in the mountains have been performed by V. I. Danileyko [138], while the mutagenic effects induced by the UV component of the solar spectrum have been studied by L. I. Yerokhina and S. I. Alikhanyan of the Institute of Atomic Energy im. Kurchatova of the Academy of Sciences USSR, located in Moscow [686]. Some work has even been done on the biological effects of solar radiation at sea level. Thus, N. A. Shul'ts and Z. A. Serdrishcheva have been charting the dynamics of functional leukopenia in relation to the 11-year solar cycle [532, 550, 551]. While this is not, strictly speaking, a current problem of space-oriented radiobiology, there can be little doubt that variations in the solar cycle would have considerable effects on spaceflights of long duration.

WEIGHTLESSNESS

The possible effects of weightlessness on living organisms has been a concern of space biology and space medicine from the very beginning. Most of the leaders in the Soviet bioastronautics effort have devoted themselves to this problem at one time or another. Of all the Soviet scientists specializing in bioastronautics, probably none stands closer to the problem of the physiological effects of weightlessness than I. I. Kas'yan, who has worked on this problem since pre-orbital flight days. In this work he was closely associated with V. I. Yazdovskiy and V. I. Kopanev. Yazdovskiy, of conise, has been interested in the problem from the point of view of the physical fitness of the cosmonauts [282, 289, 676]. The success of the first orbital flights indicated that living organisms could withstand weightlessness for periods of several days without any serious physiological consequences. However, the problem still arouses a certain amount of concern. Thus, in early 1964 V. I. Yazdovskiy, I. I. Kas'yan, and V. I. Kopanev began to express doubts about the effect of prolonged weightlessness on cardiovascular function [678]. Their concern centered around two problems: detraining, and decalcification of the skeletal bones. Similar concern was expressed by O. G. Gazenko and V. V. Parin at the 1964 COSPAR meeting, held in Florence, Italy, in May 1964 [193, 651]. Curiously enough, the paper on manned spaceflight by Yu. M. Volynkin, V. V. Parin, and P. V. Vasil'yev, presented at the same meeting, made some effort to play down the hazards of spaceflight. However, this may be accounted for by the fact that these three scientists are very much interested in seeing the manned spaceflight program continued. There can be little doubt that scientists like V. V. Parin, O. G. Gazenko, and V. I. Yazdovskiy are currently interested in the possibilities of protective adaptation of the organism and are attempting to determine the limits of adaptation to a weightless state [466].

Effects on motor activity and coordination of movements

One of the first aspects of weightlessness to be studied was its effect on motor activity and coordination of movements. Thus, in the late 1950's, V. S. Gurfinkel', P. K. Isakov, V. B. Malkin, and V. I. Popov studied the effect on human motor functions of decreased gravitation in high-speed elevators [241]. V. I. Yazdovskiy, Ye. M. Yuganov, and I. I. Kas'yan studied the orienting reflexes of animals in sub-orbital rocket flights [667, 692]. B. A. Zhuravlev studied the formation of new motor habits in the dogs Belka and Strelka, who were sent aloft in special harnesses in the Second Orbital Spaceship. Movements of the dogs were monitored by television. It was found that the establishment of the standing habit was accomplished by the fifth orbit and required an estimated 1300 to 1500 attempts [731]. Kitayev-Smyk studied the postural reactions of animals in short-term parabolic flights [311]. M. B. Zabutyy has studied the problems of equilibrium and motor

coordination in both humans and animals under conditions of partial weightlessness [708]. More recently, V. I. Yazdovskiy, assisted by I. I. Bryanov, L. I. Kakurin, Yu. V. Krylov, and M. A. Cherepakhin, has been conducting studies of sensory-motor coordination under conditions of prolonged weightlessness during actual spaceflight [673]. The most systematic study of this problem is being conducted by L. V. Chkhaidze at the Georgian Institute of Physical Culture in Tbilisi. Chkhaidze, working alone, began his research by tackling the basic problems in studying coordination of human voluntary movements from a biophysical point of view, and gradually expanded his work to include the effect of changes in gravitational field on the coordination of human voluntary movements. These studies involve not only the effects of weightlessness, but also the effects of excess gravity achieved by acceleration. Chkhaidze then applied his findings to the creation of a systematic program for the physical training of cosmonauts. It is not known whether these studies were initiated as part of the Soviet spaceflight program. However, the publication of his articles in Problems of Space Biology indicates that the value of his work for bioastronautics has been recognized [129, 130, 131, 132, 133, 134, 135]. It is believed that his present work involves the application of cybernetic analysis to his findings.

Effects on sensory illusions

Ye. M. Yuganov, I. I. Kas'yan, N. N. Gurovskiy, V. I. Yakubov, and V. I. Yazdovskiy have also conducted studies of short-term weightlessness in parabolic flights [693]. Yuganov, working with I. I. Kas'yan and V. F. Asyamolov at the Institute of Normal and Pathological Physiology, has also studied the bioelectric activity of skeletal muscles during exposure to alternating acceleration and weightlessness in short term parabolic flights [697]. L. A. Kitayev-Smyk, also working with the problem of short term weightlessness during parabolic flights, has been concerned with determination of variations in tolerance to weightlessness in humans and study of the sensory illusions which arise during weightlessness [310, 312]. In collaboration with A. T. Zverev, Kitayev-Smyk has investigated the ability of humans to perform certain types of tasks under weightless conditions [732]. Ye. M. Yuganov, assisted by I. I. Kas'yan, M. A. Cherepakhin, and A. I. Gorshkov, has also studied sensory illusions occurring during short-term weightlessness. The purpose of these studies was to set up a scheme for classifying humans by their sensory reactions to weightlessness. They felt that such a classification could be used effectively in the selection of candidates for cosmonauts [696]. A. M. Klochkov has studied changes in the electrical activity of the cortex and subcortical structures of the brain in animals during short-term weightlessness and acceleration [319].

Effects on the vestibular functions

The effects of weightlessness on the vestibular functions have occupied the attention of M. B. Zabutyy [707]. P. V. Vasil'yev, O. G. Gazenko, L. K. Titova, A. A. Bronshteyn, and A. D. Voskresenskiy, working at the Institute of Evolutionary Physiology imeni I. M. Sechenov of the Academy of Sciences USSR, in Leningrad, have been conducting morphological and histological studies of labyrinths in animals which had been exposed to weightlessness [630]. The effects of weightlessness on the vestibular analyzer have been studied by Ye. M. Yuganov, I. A. Sidel'nikov, A. I. Gorshkov, and I. I. Kas'yan at the Institue of Normal and Pathological Physiology [701, 703]. One of Yuganov's most interesting experiments, performed with D. V. Afanas'yev, was designed to determine the minimum effective gravity required to maintain normal body posture and coordination of movements. Weightlessness was achieved by means of parabolic flights, and excess gravity by means of a small centrifuge. These experiments established that the minimum acceleration required by intact animals (rats) for the maintenance of normal posture and coordination of movements was about 0.3 G. For animals lacking labyrinths, on the other hand, an acceleration of only 0.1 G is required for compensation of motor disturbances. The data obtained in these experiments clearly shows that during weightlessness the function of the vestibular analyzer hampers rather than assists the development and normalization of new motor reflexes [702].

Effects on cardiovascular and respiratory systems

The effects of weightlessness on the cardiovascular and respiratory systems of animals and man have also received considerable attention. The outstanding researcher in this area is again I. I. Kas'yan, who is currently associated with the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR. This does not mean, however, that he was associated with this institute at the time he was studying the reactions of the cardiovascular and respiratory systems in animals during rocket flights to altitudes of 212 and 450 km [286, 287]. His more recent studies, conducted in collaboration with V. I. Kopanev and V. I. Yazdovskiy, have encompassed the effect of long-term weightlessness on the cardiovascular and respiratory systems [288, 290]. R. M. Bayevskiy and O. G. Gazenko have also been investigating the reactions of the cardiovascular systems of humans and animals during weightlessness [87].

Effects on intracranial circulation

Yu. Ye. Moskalenko, who is currently identified with the Institute of Evolutionary Physiology imeni I. M. Sechenev of the Academy of Sciences USSR, in Leningrad, has been investigating blood circulation in the brain for several years. In the late 1950's, Moskalenko (who was then associated with the Department of Normal Physiology of the First Medical Institute imeni I. P. Pavlov), collaborated with A. I. Naumenko on the design of an EPG (electroplethysmograph) for the purpose of studying intracranial hemodynamics [425, 426]. During the 1960's, Moskalenko has worked with R. M. Bayevskiy and O. G. Gazenko on cerebral blood circulation under conditions of an altered gravitational field. These studies included the effects of weightlessness on the cerebral blood supply [427, 428]. More recently, he has been working with N. N. Benua and O. V. Graunov on cranial hemodynamics during variations in the direction of the gravitational field [429]. In his most recent studies, Moskalenko, working with O. V. Graunov, O. G. Gazenko, I. I. Kas'yan, and A. A. Shurubura, has been investigating adaptation of the mechanism controlling cerebral circulation in response to changes in the vector of the gravitational field, and the general effect on cranial hemodynamics of prolonged exposure to excess gravities [430, 431].

Other studies of weightlessness

I. Ya. Borshchevskiy, working with G. M. Belyakov, N. N. Gurovskiy, V. S. Kuznetsov, and Ye. M. Yuganov, has investigated the quality of reception and transmission of speech under conditions of weightlessness [104]. G. P. Parfenov has investigated the effect of weightlessness on fertilization, oviposition, and early embryonic development in Drosophila melanogaster flown on the Vostok-3 and Vostok-4 flights [459].

ACCELERATION

The tolerance of living organisms to acceleration is one of the major biomedical problems of spaceflight. The centrifuge became an established tool for research on acceleration during the early days of experiments with rocket flight. Thus, G. L. Komendantov and V. V. Levashov studied the effect of transverse accelerations on man and animals as early as 1947 [323]. In the mid 1950's, V. I. Babushkin, P. K. Isakov, V. B. Malkin, and V. V. Usachev made a number of studies of the effects of transverse radial accelerations. These studies, which used both human and animal subjects, concerned not only general effects but specific effects on the central nervous system, on vision, on hemodynamics, and on general adaptability to the forces of centrifugation as well [56, 260, 623, 624]. In all probability these studies were performed at the Scientific Research Institute of Aviation Medicine. Another of the pioneer groups working on the effects of acceleration was the team of Ya. A. Rosin, G. P. Mikhaylovskiy, and P. M. Suvorov. This group was particularly concerned with the effects of acceleration on central nervous system activity [507].

Leading figures in the Soviet bioastronautics community who are currently concerned with the effects of acceleration include V. I. Yazdovskiy, I. I. Kas'yan, O. G. Gazenko, A. A. Gyurdzhian, P. V. Vasil'yev, A. D. Voskresenskiy, and others [193, 282, 629, 678]. Vasil'yev, Voskresenskiy, and Gazenko have indicated that modern trends of research in the area of acceleration fall into two major categories: 1) acceleration effects on hemodynamics and on respiratory function, and 2) acceleration effects on the central nervous system and on the role of that system in the adaptive changes of the body when subjected to accelerations.

Further research is also called for on the effect of physical factors on tolerance of animals to acceleration (the survival rate of white rats cooled under conditions of hypocapnia was twice that of intact animals after exposure of both groups to accelerations of 31 G for 5 min) [629]. V. V. Parin, O. G. Gazenko, and V. I. Yazdovskiy have been concerned with the adaptation potential of the organism to acceleration and with the limits of adaptation to maximum accelerations [466]. I. M. Khazen and D. Ye. Rozenblyum have both been studying adaptive reactions of the organism to acceleration. Khazen in particular has been preoccupied with methods of increasing the resistance of the organism to effects of acceleration [298, 511]. I. M. Khazen has also been studying the histological changes effected in animals by acceleration with E. M. Kogan and A. S. Barer [299]. Barer, in collaboration with G. A. Golov, V. B. Zubavin, and Ye. P. Tikhomirov, has been studying the tolerance limits of man to transverse accelerations [75].

Effects on the cardiovascular and respiratory systems

One of the major problems in this area is the effect of accelerations on the cardiovascular and respiratory systems. V. I. Babushkin, P. K. Isakov, V. B. Malkin, and V. V. Usachev have continued their work on the effects of radial acceleration on the cardiovascular and respiratory systems [58]. A. D. Voskresenskiy is concentrating on the changes in cardiac activity during prolonged transverse acceleration [654]. A. S. Barer, G. A. Gorlov, V. B. Zubavin, and Ye. P. Tikhomirov, using a centrifuge with an 8-m radius, are exploring the limits of respiratory and cardiovascular tolerance to transverse accelerations in human subjects [73]. Barer, working with G. A. Gorlov and Ye. I. Sorokina, has made special studies of respiratory changes which take place in man during maximum exposure to maximum transverse acceleration [76]. V. I. Babushkin and V. V. Usachev have been testing the limits of human tolerance to radial accelerations combined with elevated oxygen pressure [57]. V. I. Danileyko, A. I. Nazarenko, and O. S. Savchenko have been studying respiration in white rats during prolonged exposure to radial accelerations [139]. P. F. Vokhmyanin has been studying the interrelation between hemodynamic changes and respiration during accelerations [639]. A. A. Kiselev has been studying the effects of transverse acceleration on hemodynamics and gas exchange in pulmonary circulation [307]. R. A. Bardina, who is affiliated with the Departments of Normal Anatomy of two institutes, the Military Medical Academy imeni S. M. Kirov and the First Leningrad Medical Institute imeni I. P. Pavlov, has been studying the effects of acceleration on the walls of arteries [72]. M. G. Prives has been making similar studies in rabbits and rats, examining the vascular and lymphatic systems of test animals anatomically and histologically at various intervals after exposure to acceleration [496]. Yu. V. Mashkovtsev has been studying changes in the inguinal lymphatic plexuses of dogs exposed to centrifugation [410].

Effects on metabolic functions

V. S. Shashkov, V. V. Antipov, M. O. Raushenbakh, G. A. Chernov, and V. A. Maslennikova have studied the effect of acceleration on the serotonin level in the blood of animals [546]. I. M. Khazen and I. L. Vaysfel'd have made studies of the amounts of biologically active substances in rats during exposure to radial acceleration [297]. A. A. Gyurdzhian, M. A. Lomova, and L. A. Radkevich have been studying the nonsterified fatty acid content of the blood plasma of rats subjected to the effects of accelerations [252]. P. M. Suvorov made pioneer studies of the effects of radial acceleration on salivary and gastric gland secretion and on the periodic contraction of the stomach. Curiously enough, this study, made in 1958, was done by Suvorov for the Central Institute for the Advanced Training of Physicians in Moscow [603, 604].

Effects on tissues of organs

Numerous researchers have investigated the pathological and morphological changes induced in animals by exposure to accelerations. V. G. Petrukhin and M. M. Sokolova have investigated acceleration-induced pathological changes in the heart, the pulmonary artery, the portal vein, the brain, the kidney, and the liver [480, 481, 482]. The effects of acceleration on the structure of various viscera was studied by V. G. Yeliseyev, Yu. N. Kopayev, and Ye. F. Kotovskiy [683]. Yu. N. Kopayev studied the effects of transverse accelerations on the histological and morphological structure of the pancreas [330], Yu. N. Korolev on the lungs [335], Ye. F. Kotovskiy on hepatic structure [346], and Yu. I. Afanas'yev and V. V. Korolev on the renal tissues of dogs [4, 334].

Effects on the central nervous system

The effect of acceleration on the central nervous system is another major problem in this area. Several teams have studied the effects of acceleration on the bioelectric activity of the brain. One such team, consisting of G. V. Izosimov and A. N. Razumeyev, has studied the effects of accelerations of various magnitudes and durations on the electrical reaction of the cerebral cortex of animals and of man [270, 271]. Razumeyev has made similar studies with the aid of P. M. Suvorov, using EEGs to detect changes in various parts of the brain [503]. A. M. Klochkov has studied the electrical activity of both the cortex and the subcordical formations of animals during exposure to acceleration [319]. In 1962, studies were conducted by O. G. Gazenko, aided by B. B. Yegorov (the physician cosmonaut), G. V. Izosimov, Yu. P. Limanskiy, A. N. Razumeyev, and P. M. Suvorov, on the effects of prolonged exposure to acceleration on the bioelectric activity of various areas of the brain [191]. Most recently, O. G. Gazenko, working with his student B. B. Yegorov, has made a study of the changes in the neuron rhythm of the reticular formation during transverse acceleration [195]. Other investigators, such as V. Ye. Belay, P. V. Vasil'yev, and S. P. Kolchin, have studied the effects of prolonged transverse accelerations on the functional condition of the central nervous system in animals [90]. A team consisting of E. V. Marukhanyan, P. K. Isakov, B. F. Asyamolov, G. I. Pavlov, and V. V. Usachev has been making electrophysiological studies of cutaneous motor analyzer functions during acceleration [408]. S. I. Nudman, working in the Laboratory of Comparative Ontogenesis of Higher Nervous Activity of the Institute of Physiology imeni Pavlov of the Academy of Sciences USSR, has studied the deleterious effects of rotation on the conditioned motor reflexes of rats. He found that rotation has a more deleterious effect on auditory conditioned reflexes than on visual ones [446]. A. B. Flekkel' has studied the effect of angular velocity of rotation on the state of various visual functions (visual acuity, flicker fusion threshold, and field of vision) [169].

Several investigators have been studying the structural rather than the functional effects of acceleration on the brain and the central nervous system. Thus, V. G. Petrukhin and D. I. Medvedev have made independent studies of the dynamics of morphological changes in the brain cortex of animals subjected to transverse accelerations [417, 480]. B. S. Glushkov has studied the morphological changes produced by transverse accelerations in the neural tissue of the nervous system and particularly the spinal cord of animals [218]. V. A. Otellin has studied the effects of acceleration on the nervous system in the extremities (i.e., limbs) [454].

Effects on intracranial hemodynamics

The effect of acceleration and other spaceflight factors on intracranial hemodynamics has been one of the major concerns of bioscientists working on spaceflight problems. The major researcher in this area has been Yu. Ye. Moskalenko. In the mid-1950's, Moskalenko collaborated with A. I. Naumenko at the Department of Normal Physiology of the First Leningrad Medical Institute imeni Pavlov in the development of an EPG (electroplethysmograph) for the study of intracranial hemodynamics [425]. Moskalenko continued his studies in the late 1950's at the Institute of Evolutionary Physiology imeni I. M. Sechenev of the Academy of Sciences USSR in Leningrad [426]. Aided by R. M. Bayevskiy and O. G. Gazenko, Moskalenko developed a methodology for studying cerebral blood circulation under spaceflight conditions by means of the EPG which he had designed. This methodology was tested in dogs on centrifuges [427, 428]. More recently Moskalenko has continued these studies with the aid of N. N. Benua, O. V. Graunov, O. G. Gazenko, and I. I. Kas'yan [429, 430]. The latest of these experiments, performed at the Institute of Evolutionary Physiology in Leningrad, dealt with the hemodynamics of the cerebrovascular system during prolonged exposure to excess gravities. This work was done with the collaboration of O. G. Gazenko, A. A. Shurubura, I. I. Kas'yan, and O. V. Graunov [43].

Besides the work on detection and measurement of changes in cranial circulation performed under the direction of Moskalenko, numerous researchers have been investigating the role of the nervous system in the control of hemodynamic shifts in animals and human subjects exposed to acceleration. B. M. Savin is one such investigator [524]. G. I. Mchedlishvili of the Institute of Physiology of the Georgian Academy of Sciences in Tbilisi has been investigating the role of the carotid sinus in the control of cerebral circulation [416]. The role of carotid sinus reflexes has also been studied by Yu. V. Nikolayenkov under conditions of lowered barometric pressure [443]. V. A. Klimovitskiy has concentrated on the effects of acceleration on cerebral venous blood circulation in animals [317, 318]. A team consisting of Ye. A. Kovalenko, V. L. Popkov, and I. N. Chernyakov has investigated the effects of transverse accelerations on the oxygen concentration in brain tissues [349, 350, 352].

Effects on the vestibular analyzer

The effect of acceleration on the vestibular analyzer is one of the problems most specifically related to spaceflight. The great interest which this question has for researchers like Ye. M. Yuganov stems from the fact that it has very specific implications for the selection and training of cosmonauts. Yuganov, working with A. I. Gorshkov, has subjected humans to radial accelerations, Coriolis acceleration, and to galvanic current in order to test the excitability of the vestibular analyzer [701]. With another researcher, D. V. Afanas'yev, Yuganov has performed experiments to test the effect of artificial gravity on the vestibular analyzer [702]. A. V. Lebedinskiy has directed a large research group, consisting of N. I. Arlashchenko, V. Ye. Busygin, R. A. Vartbaronov, A. S. Veselov, N. A. Volokhova, Yu. G. Grigor'yev, M. D. Yemel'yanov, T. V. Kalyayeva, Yu. V. Krylov, B. I. Polyakov, and Yu. V. Farber, in the study of the effect of prolonged exposure to Coriolis accelerations of small magnitude on the human organism [384]. Lebedinskiy has also studied the effect of angular accelerations on vestibular functions in collaboration with Yu. G. Grigor'yev, R. M. Lyubimova-Gerasimova, and B. I. Polyakov [385]. S. S. Markaryan has also studied vestibular reactions during the exposure to angular accelerations in human subjects [406]. A. A. Gyurdzhian and Z. I. Apanasenko have studied the functional state of the vestibular mechanism in white rats raised under conditions of daily (chronic) acceleration [253].

At the Institute of Evolutionary Physiology imeni I. M. Sechenev of the Academy of Sciences USSR in Leningrad, a research team including P. V. Vasil'yev, Ya. A. Vinnikov, O. G. Gazenko, L. K. Titova, A. A. Bronshteyn, A. D. Voskresenskiy, V. I. Govardovskiy, and I. V. Osipova has been conducting morphological, histological, and cytochemical studies of the utriculus and the vestibular portion of the labyrinth of animals which had been exposed to variable gravitational fields by means of centrifugation [630, 633, 634, 635]. R. Ye. Kogan and S. S. Markaryan have also been making studies of morphological changes arising in labyrinths of animals under the influence of radial accelerations [320]. R. Kh. Gambarova has made an interesting study of the role of the vestibular organ in the regulation of the blood sugar level. She found that in normal rabbits variations in blood sugar level were a function of the duration, speed, and repetition of rotation [176].

Effects of prolonged acceleration

Apparently, little work on the effects of chronic acceleration has so far been done in the USSR (O. G. Gazenko said as much at the International Space Symposium, held in San Antonio, Texas, November 1964). Some experiments on the effects of prolonged accelerations in animals have already been mentioned. To those should be added the experiments performed by

A. R. Kotovskaya and Ye. M. Yuganov [342, 343]. Kotovskaya, working with P. V. Vasil'yev, B. A. Lapin, S. F. Simpura, I. S. Grishina, and V. I. Kulinskiy, has also tested the effect of prolonged transverse accelerations on monkeys [345]. S. A. Gozulov has worked on the problem of the cumulative effects of accelerations [232]. N. I. Arlashchenko, B. B. Bokhov, B. Ye. Busygin, N. A. Volokhova, Yu. G. Grigor'yev, B. I. Polyakov, and Yu. V. Farber, working under the direction of Professor Lebedinskiy, have studied the effect of prolonged Coriolis accelerations in a slowly rotating MVK-1 chamber [48]. A. A. Marinichev has designed a special appliance for recording human EEGs during prolonged rotation of the subject in a Barany chair [405].

Effects of impact accelerations

Studies of impact accelerations seem to have been relatively few, or else to have been little reported. The most active scientists working in this area appear to be S. A. Gozulov and G. B. Mirolyubov, each of whom seems to have made a number of studies of this problem [234, 235]. G. P. Mirolyubov has also studied the effect of impact accelerations on animals immersed in water and on animals supported by contour-molded restraint systems [423, 424]. Mirolyubov has also worked with M. I. Kas'yanov on pathological and morphological changes in the internal organs of animals resulting from impact accelerations [291]. The tolerance of animals to longitudinal impact accelerations has been studied by Ye. M. Yuganov, I. I. Kas'yan, and V. I. Yazdovskiy at the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR [694].

Other acceleration studies

In concluding the section on acceleration, a few special studies should be mentioned. Thus, I. V. Orlov has studied the caloric nystagmus threshold during rotation at a constant speed [453]. Another experiment involving increase in temperature due to acceleration has been performed by V. V. Matsynin, who conducted a series of experiments on the effect of acceleration on the generation of heat in albino rats [411]. K. V. Ivanov, M. V. Zhukov, and M. G. Molchanova have studied the effect of accelerations on the course of radiation sickness [265]. Yu. M. Volynkin, P. P. Saksonov, V. V. Antipov, and I. A. Savenko have also studied the effect of acceleration and of vibration on the course of radiation injuries. They found that if these stressors are applied on the 5th to 7th day after exposure to radiation, they tend to aggravate the severity of radiation injury, while if they are applied prior to irradiation they mitigate the severity of radiation damage

[647]. N. A. Agadzhanyan and A. R. Mansurov have studied the effect of prolonged radial accelerations on animals subjected to hypoxia [7]. V. P. Dudaryev has studied the effect of adrenalectomy on the acceleration tolerance of rats which had been adapted to hypoxia [163]. Another research group consisting of V. I. Baranov, A. A. Gyurdzhian, M. A. Lomova, L. A. Radkevich, L. T. Tutochkina, T. A. Fedorova, L. P. Furayeva, S. S. Khnychev, and N. S. Artem'yeva has studied the influence of chronic accelerations on the development of rats [64]. P. V. Vasil'yev and V. Ye. Belay have been studying the effect of certain pharmacological agents on the resistance of organisms to acceleration. Their experiments indicate that the use of anti-acceleration drugs which change the functional state of the organism makes it possible to increase the organism's resistance to the effects of acceleration [631].

GAS ENVIRONMENT AND RESPIRATORY PROBLEMS

The gas environment and respiratory problems of bioastronautics evolved directly out of the problems of high-altitude physiology which were one of the major concerns of aviation medicine. With the advent of the space age, gas environment and respiratory problems have tended to become more critical, due to the requirement for fully airtight spaceship cabins and to the eventual necessity of providing closed environmental systems which will provide regeneration of air. These space age problems have given new impetus to certain areas of research, such as the effects of excess pressure or the effects of altered respiratory mixtures which may contain unusual amounts of oxygen or in which the nitrogen of the air may be replaced by helium. Hypoxia, however, remains the central problem, or at least the problem which has attracted the greatest amount of attention from Soviet researchers. In addition to research on the effects of hypoxia and on the mechanisms of adaptation to prolonged hypoxia, studies have been made in the effort to find antihypoxia drugs, and on the combined effects of hypoxia and acceleration, hypoxia and radiation, hypoxia and low temperatures, and the effect of hypoxia on motion-sickness.

Effects on cardiovascular and respiratory functions

Changes in the basic physiological functions of man during prolonged exposure to lowered barometric pressure and limited spatial environment have been studied by D. I. Ivanov, V. B. Malkin, I. N. Chernyakov, V. L. Popkov, and Ye. O. Popova [263]. V. B. Malkin, working with A. F. Yurkov, has also studied the effect of acute oxygen deficit on adrenalectomized and hypophysectomized rats [400]. Perhaps the greatest amount of attention has been devoted to the effects of hypoxia on the cardiovascular system and on respiratory functions. One of the teams active in this area of research is headed by A. G. Kuznetsov. Together with N. A. Agadzhanyan, Yu. P. Bizin, N. I. Yezepchuk, I. R. Kalinichenko, L. I. Karpova, I. P. Neumyvakin, and M. M. Osipova, Kuznetsov has studied the effect of prolonged exposures to conditions of lowered barometric pressure on the respiratory and cardiovascular functions [373]. V. L. Popkov and I. N. Chernyakov have made EKG studies of the cardiovascular reactions of dogs to hypoxia and other high-altitude factors [490]. V. N. Alifanov and L. M. Lemesheva have made a study of the effects of acute hypoxia on the bioelectric activity of the human myocardium, using vectorcardiographic analysis [24]. V. N. Alifanov has also made studies of the effects of hypoxia on the biomechanics of respiration [23]. A. M. Kulik has studied the biomechanics of respiration under conditions of hypoxia and hypercapnia [363]. A. V. Beregovkin, P. V. Buyanov, and V. B. Malkin have studied respiration and gas exchange during acute hypoxia [94], while A. D. Slonim has studied variations in the gas metabolism during hypoxemia [590].

Effects on the central nervous system

One of the major concerns of Soviet researchers is the effect of hypoxia on oxygen tension in the brain tissues. This problem has been studied by Ye. A. Kovalenko and V. B. Malkin by means of electroencephalography [347]. Ye. A. Kovalenko, with V. L. Popkov and I. N. Chernyakov, has used the polarographic method to determine oxygen tension in brain tissue during exposure to high-altitude flight factors [354]. Of particular interest is the work of Yu. V. Nikolayenkov, who studied the role of the carotid sinus reflexes on the mechanism of cerebral circulation under conditions of lowered barometric pressure [443]. V. B. Malkin has also studied the effects of hypoxia on the central nervous system with the aid of EEG [401]. Studies of the effects of high-altitudes on the general state of the human nervous system were made by Ye. N. Kutchak [366]. More specific studies have been made by L. I. Ardashnikova, working in the Laboratory of General Physiology of the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR. She studied the effects of hypoxia on the conditioned reflex activity in dogs [46]. B. S. Frantsen and A. I. Yusfin have studied the effects of hypoxic conditions on color vision [171], while E. V. Bondarev (who is described as a member of the Electrophysiology Laboratory of the Department of Aviation Medicine) has studied the effects of hypoxia on the auditory analyzer in cats [100]. S. N. Sergeyev has made histochemical analyses of the effect of hypoxia on various visceral organs [535]. B. M. Braginskiy, A. G. Glushchenko, O. G. Lorentz, and G. L. Mednik have studied the effects of hypoxia on the functional activity of the adrenal cortex [107]. A. S. Barer and E. V. Yakovleva have studied the variations in the sodium and potassium ion concentrations in urine and saliva of human subjects after exposure to hypoxic conditions [74].

Adaptation to hypoxia

Numerous researchers have investigated the process of adaptation to hypoxia and acclimatization to high altitudes. These include N. N. Sirotinin, who has pursued these studies for the purpose of developing therapeutic procedures for treating conditions involving oxygen starvation [563]; L. G. Filatova, whose interest in this problem was more generalized [168]; and I. P. Plotnikov, who attacked this problem with the aid of ballistocardiography [485]; N. A. Verzhbinskaya, working at the Institute of Physiology of the Academy of Sciences USSR in Leningrad, who has been studying the cellular mechanism of adaptation to lowered oxygen pressure [632]; and V. I. Voytkevich, who has been studying the problems of adaptation to chronic hypoxia in rats [655].

Certain Soviet researchers, such as I. N. Bel'gova and S. V. Osipova [91], E. F. Shamray [543], G. I. Gurvich, and K. S. Shadurskiy [243], and S. Ya. Dubich [159], have been searching for drugs which would help increase the resistance of man and animals to hypoxia. So far the results

have not been too satisfactory, but the search continues.

Hypoxia and acceleration

It is natural that the space age should have led to the study of the effects of hypoxia combined with other spaceflight factors, such as acceleration and radiation. Among the leaders in studies of the combined effects of accelerations and altered oxygen pressure are V. I. Babushkin, V. V. Usachev, P. K. Isakov, and V. B. Malkin [56, 57]. N. A. Agadzhanyan and A. R. Mansurov have also been studying the effects of prolonged accelerations and hypoxia on animal organisms [7]. Ye. A. Kovalenko, V. L. Popkov, and I. N. Chernyakov have been studying the effects of excess oxygen pressure and acceleration on the oxygenation of the brain tissues [349, 350, 352]. V. P. Dudaryev has been studying the effect of adrenalectomy on the resistance to centrifugation in rats which have been adapted to hypoxia [163].

Hypoxia and radiation

Several studies have also been performed on the combined effects of hypoxia and radiation. This is essentially a radiobiology problem, since researchers have discovered that adaptation to hypoxia tends to increase resistance to radiation. G. A. Vasil'yev has worked on this problem since 1958, and was still working on it with V. A. Belyayev as late as 1963 [627, 628]. I. B. Bychkovskaya has been studying this problem at the Department of Experimental Morphology of the Central Scientific Research Institute of Medical Radiology [119]. Ye. P. Smolichev and Yu. G. Ponomarev have been investigating the combined effects of high-altitude factors and x-rays on changes in the albumin levels of the blood serum [593]. A. A. Sarkisyan, S. A. Khachatryan, and A. B. Zakaryan, taking as their point of departure Orbeli's premise that adaptation to hypoxia reduces mortality in animals exposed to ionizing radiation, conceived the idea of investigating whether the duration of clinical death could be prolonged in animals adapted to hypoxia. Experiments conducted at the Experimental Station on Mt. Aragats by these three researchers from the Yerevan Institute of Medicine have shown that dogs acclimatized to hypoxia could withstand longer periods of clinical death than dogs which were not so acclimatized [641]. M. M. Konstantinova, noticing that the antiradiation effect of hypoxia is related to a drop in body temperature, has been investigating the inter-relationship of the three factors [327]. The relationship between hypothermia and hypoxia has also been investigated by N. V. Korostovtseva [336], and by a team consisting of Ye. A. Kovalenko, V. I. Korol'kov, and Ye. A. Il'in [351]. V. A. Aver'yanov, in a series of experiments performed at the Military Medical Academy imeni S. M. Kirov in Leningrad, has shown that low environmental

temperatures also reduce the frequency and severity of decompression sickness [55]. N. A. Razsolov has been testing the effects of hypoxia on motion-sickness. The nature of his experiments leads one to suspect that this is part of the cosmonaut selection and training program [502].

Decompression studies

Decompression phenomena have also occupied the attention of Soviet bio-astronautics specialists. The problem, which involves tissue emphysema, was studied in 1957 by A. G. Kuznetsov [371], and in 1958 by N. A. Agadzhanyan [8] and A. P. Brestkin [114]. Decompression phenomena in the human body under conditions of extremely low barometric pressure were studied by P. N. Ivanov, A. G. Kuznetsov, V. B. Malkin, and Ye. O. Popova in 1960 [266]. The more dramatic effects of explosive decompression have been studied by V. I. Nikolayeva in 1959 [444], and more recently by Ye. A. Kovalenko [348]. A team consisting of V. I. Yazdovskiy, A. P. Mansurov, N. A. Agadzhanyan, and A. S. Tsivilashvili has studied the effects of explosive decompression on various organs and tissues at the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR [668]. Similar studies have been performed by A. G. Kuznetsov, A. S. Tsivilashvili, and A. P. Mansurov [372].

Effects of excess pressures

The use of pressure suits and spacesuits has led to a number of researchers to investigate the effects of respiration under excess pressure. The following investigators worked on this problem in the early 1950's: B. A. Botvinnikov, I. Sh. Ginzburg, P. M. Gramenitskiy, G. I. Ivanov, O. I. Ivchenko, Yu. M. Libin, N. M. Rudnyy, L. P. Salmonov, L. A. Fel'dman, and G. N. Freyman [105]. V. N. Alifanov, M. I. Vakar, A. V. Yeremin, and A. Ye. Ivanov have studied the effects of pressure breathing under conditions of a rarefied external atmosphere [25]. D. I. Ivanov has investigated the problems of hemodynamics during respiration of oxygen under elevated intrapulmonary pressure [262]. V. G. Voloshin has investigated the oxygen supply of the heart during respiration under excess pressure [640]. A. V. Yeremin and V. N. Alifanov have investigated respiration tolerance during excess pressure [685].

Effects of altered partial pressures

Problems connected with the development of space cabin atmospheres and closed ecological systems have led to many experiments on the effects of changing the partial pressures of oxygen and carbon dioxide. It is interesting to note that most of these studies have been published only since January 1963. I. I. Antonov, for example, has studied the effects of changing the partial pressure of oxygen on the thermal regulatory function of the organism [42]. N. S. Zayko, M. I. Kuznetsov, and N. A. Chelnokova, working at the Laboratory of Physiology and Pathology of Sensory Organs of the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR, have studied the effects of prolonged pure oxygen respiration on the gustatory sensibilities of man [710]. I. S. Breslav, A. G. Zhironkin, E. A. Konza, Ye. N. Salatsinskaya, and G. V. Troshkhin studied the gas exchange dynamics in white mice exposed to high oxygen tension at the Institute of Physiology imeni I. P. Pavlov of the Academy of Sciences USSR in Leningrad [110]. A team consisting of Ye. A. Kovalenko, V. L. Popkov, and I. N. Chernyakov has studied brain tissue oxygenation during pure oxygen respiration and respiration of atomospheres consisting of 90—95% oxygen and 5—10% carbon dioxide [353]. S. G. Zharov, Ye. A. Il'in, Ye. A. Kovalenko, I. R. Kalinichenko, L. I. Karpova, N. S. Mikerova, M. M. Osipova, and Ye. Ye. Simonov have performed interesting studies of the effects on men kept in pressure chambers with a 7 cubic meter capacity of prolonged respiration of an atmosphere with an increased CO_2 content [713]. G. P. Doronin has studied the effects of atmospheres with an increased CO_2 content on conditioned reflexes [158]. N. M. Ryzhova has studied the effects of increased CO_2 in the atmosphere on the blood vessels of the brain, the leg muscles, and the kidneys, at the Institute of Normal and Pathological Physiology [514]. V. N. Zagryadskiy and Z. K. Sulimo-Sumuyllo have studied the effects of ultrahigh and ultralow CO_2 content in the air on compensatory reactions of the organism (i.e., hypercapnia and hypocapnia) [709]. At the Institute of Physiology imeni I. P. Pavlov of the Academy of Sciences USSR in Leningrad, I. S. Breslav made some interesting experiments in which white mice were given a chance to express their preference for gas media with various oxygen and carbon dioxide gradients [109].

Effects of elium and closed ecological systems

Perhaps the most interesting of the experiments on altered respiratory media are those involving helium. The outstanding specialist in this area appears to be A. G. Dianov, who, together with A. G. Kuznetsov, has been working on the possibility of substituting helium for nitrogen in the respiratory atmosphere for spaceship cabins [151]. Dianov has also investigated the effectiveness of helium—oxygen mixture for the ventilation of spacesuits [152]. V. V. Boriskin, P. A. Gul'tyayev, and B. M. Savin have studied the effects of a helium—oxygen atmosphere on the development of chicken and frog embryos and on baby chickens [101]. The effects of respiratory gas mixtures

containing various amounts of helium on the auditory analyzer of the brain in animals and in man have been studied by E. V. Bondarev [99]. Perhaps no problem is as germaine to the current state-of-the-art in the area of respiratory physiology as that of the effects of a closed ecological system on physiological functions. Experiments in this area were performed by I. S. Breslav of the Institute of Physiology of the Academy of Sciences USSR in Leningrad, together with A. G. Zhironkin, A. M. Il'nitskiy, E. A. Konza, M. I. Mityushov, A. D. Nozdrachev, Ye. N. Salatsinskaya, G. V. Troshikhin, and A. M. Shmeleva. These experiments involved a closed oxygen circulation system for small animals [108, 111]. The effects of small concentrations of carbon monoxide on the human organism in airtight cabins were studied by V. Ya. Gilinskiy, A. V. Chapek, A. G. Kozlova, N. M. Kulikova, and A. Ya. Loshak [204]. P. I. Bogatkov, Yu. G. Nefedov, and M. I. Poletayev studied exhaled air as a source of carbon monoxide contamination in sealed chambers [97]. More recently, the gaseous products of the vital activity of man have been carefully analyzed by a team consisting of G. M. Gorban', I. I. Kondrat'yeva, and L. T. Poddubnaya [224].

CHLORELLA AND HIGHER PLANTS

Even though there has been a certain amount of disappointment in Chlorella as a means of regenerating air and providing food on prolonged spaceflights, a large amount of research has been performed with Chlorella in the USSR. The nature of the experiments performed clearly indicates that the Soviets have seriously entertained the idea of using Chlorella in life support systems as an air regenerator and food source.

Chlorella culture studies

One team, consisting of M. M. Korotayev, V. V. Kustov, G. I. Meleshko, L. T. Poddubnaya, and Ye. Ya. Shepelev, has not only investigated methods for increasing the photosynthetic productivity of chlorella cultures in equipment used for the biological air regeneration, but has also studied the nature of the toxic gaseous substances liberated during vital photosynthesis by Chlorella pyrenoidosa S-39 [337, 418]. While this group seems to have been working with Chlorella as part of an actual spaceflight system for biological air regeneration, the basic research on the use of Chlorella for spaceflight purposes was performed at the Institute of Plant Physiology imeni K. A. Timiryazev of the Academy of Sciences USSR, by a team consisting of A. A. Nichiporovich, V. Ye. Semenenko, and M. G. Vladimirova. Working in the Photosynthetic Laboratory of this Institute, this group has apparently studied many aspects of the Chlorella problem. Thus, they made a comparative study of the productivity of various forms of unicellular algae [638], using serveral different varieties of Chlorella (including thermophilic varieties) and certain species of Scenedesmus. These algae were cultured using various media and cultivation methods, including cultivation under intensive light. This team has also studied the problem of cultivation of high-density algal cultures under intense illumination [531], and has devised a special culture device, the UIV-1 device for the intensive cultivation of algae. This piece of equipment was built for them by the Central Design Bureau of the Academy of Sciences USSR, in 1960-1961 [527, 442]. Besides these studies, two other members of the staff of the Institute of Plant Physiology, K. S. Spektorov and Ye. A. Lin'kova, have developed a new simplified method for obtaining synchronous cultures of Chlorella [597]. Any doubt that may have existed concerning the official nature of the relationship between Chlorella experiments carried out at the Institute of Plant Physiology and the Soviet spaceflight program is completely dispelled by the fact that is was Semenenko and Vladimirova, under the direction of A. A. Nichiporovich (with A. A. Gyurdzhian acting as consultant), who performed the spaceflight experiments with Chlorella on the Second Orbital Spaceship [529, 530]. The purpose of these experiments was to test the effects of a 24-hour exposure to spaceflight conditions on cultures of Chlorella pyrenoidosa [526].

Chlorella and microorganisms

M. G. Vladimirova has also studied the heterotrophic microflora present in chlorella cultures [636]. Together with L. N. Bazaitova, Vladimirova studied the development of Chlorella pyrenoidosa cultures containing bacteria of the Pseudomonas group [637]. N. B. Zabarzina has made a study of the lytic agent in cultures of Chlorella pyrenoidosa. She discovered that lysis in Chlorella cultures occurs as a result of the combined effects of a specific phage and Caulobacter vibriodes. She also tested the effects of a number of antibiotics on Chlorella cultures. In this work she encountered certain difficulties because most of the antibiotics which were effective in preventing lysis were either toxic to chlorella or retarded its growth [705, 706]. Zabarzina performed her work at the Institue of Microbiology of the Academy of Sciences USSR [705], but other researchers working at the Department of Biological and Soil Sciences of the Moscow State University have also been studying the interrelationship between algae and microorganisms. Thus, N. V. Davydova, V. V. Pospelova, and M. M. Telichenko have studied the effect of Chlorella vulgaris and Scenedesmus obliquus cultures on the survival of Salmonella typhimurium bacteriophages [141]. V. I. Maksimova and K. D. Lastochkina have studied the problem of bacterial mortality in algal cultures [397]. Maksimova, working with N. M. Pimenova, has also studied the effects of various antibiotics on cultures of Chlorella, Scenedesmus, and other algae [396].

Other Chlorella studies

The "Chlorella problem" has been attacked from many angles by various researchers. A. M. Stepanova studied the effect of illumination on the growth and photosynthesis of chlorella cultures [599]. V. N. Shaposhnikov, M. N. Pimenova, I. V. Maksimova, Ye. N. Zhdannikova, and A. A. Ramenskaya studied the seasonal periodicity of various green algae under laboratory conditions [545]. N. V. Trukhin studied the effect of temperature and optimum light on the growth of Chlorella pyrenoidosa at the Institue of Biology of Water Reservoirs of the Academy of Sciences USSR [621]. L. G. Yaglova studied changes in the ion balance in algae due to effect of light [656]. V. M. Kutyurin, M. V. Ulubekova, N. M. Nazarov, and A. P. Vinogradov studied the effect of various oxygen concentrations on the photosynthesis and respiration rates in various algae [367]. T. B. Galkina performed experiments to determine the effect of the re-use of nutrient media on the growth of continuous Chlorella cultures [175]. P. A. Kolesnikov and L. O. Eynor studied the role of ascorbic acid in the oxygen metabolism of Chlorella [322]. G. P. Serenkov studied the nucleotide composition of DNA in algae [533]. N. M. Sisakyan, E. N. Bezinger, and M. G. Shaposhnikova studied the aminoacid composition of Chlorella pyrenoidosa [579].

Automatic culturing

A team consisting of S. V. Tageyeva, A. V. Brandt, V. S. Korshunova, and I. P. Generozova has studied the optical properties of synchronous cultures of Chlorella pyrenoidosa. An earlier reference indicate that this work was performed at the Department of Biological and Soil Sciences of Moscow State University [611], but more recent (1963) references indicate that this work was performed at the Insitute of Biophysics of the Academy of Sciences USSR [613, 614]. Tageyeva and her co-workers feel that a knowledge of the optical parameters of various algae strains can be used in calculating and designing equipment for obtaining high-productivity cultures of unicellular algae. The problem of automatic control of algae culturing for spaceflight has been studied by Ye. A. Ivanov and I. V. Aleksandrova [267, 268, 269]. A team consisting of I. I. Gitel'zon, I. A. Terskov, V. A. Batov, O. G. Baklanov, and B. G. Kovrov has designed a self-regulating system for controlling algal cultures in closed ecological systems [205]. Another source states that a device for the automatic production of Chlorella has been designed by the Algal Culture Laboratory of the Biological Institute of the Leningrad State University [98]. It may be that this refers to the work of I. I. Gitel'zon and his co-workers, but the possibility that more than one team is working on the design of such equipment should not be overlooked. I. V. Smirnov, subjecting the problems of mass cultivation of Chlorella to mathematical analysis, demonstrated that symmetrical cultivation vessels are more efficient than asymmetrical vessels [592]. The scope and diversity of all of these various studies of Chlorella and its relatives is to some extent indicative of Soviet interest in finding an agent for regenerating air for spaceflights of long duration. Whether Chlorella cultures will continue to be studied with the same intensity of effort in the future is not known. It is known that because of the many uncertainties of depending on Chlorella for regeneration of air, Soviet thinking has been turning more and more to chemical photosynthesis as a solution to the problem. The description of Soviet effort in studying the phenomenon of photosynthesis is largely a biophysical and biochemical problem and will be the subject of a separate report.

Higher plant studies

In any case, Soviet scientists have already stated for the record that they will not rely on Chlorella alone. Future spaceships will carry higher plants as well. Ye. V. Lebedeva has been working on the problem of finding artificial substrata for hydroponic cultivation of plants in spaceships. Among modern structural materials which possess high porosity and low specific weight thus far tested as substrata, "vermiculite" gave the best results. Plants gown on "vermiculite" produced leaves, roots, stems, and fruit whose weight was two to three times that of plants grown on other substrata [378]. Working towards the same goal, V. G. Chuchkin and V. I. Rozhdestivenskiy have been studying the effects of various nutrient media on

photosynthesis in higher plants [137]. The testing of seeds and sprouts of higher plants on the Vostok spaceships is an indication that higher plants definitely have been assigned a role in the Soviet spaceflight program Studies of the effects on higher plants of high-intensity radiation at high altitudes are also an indication that Soviet scientists believe that higher plants will not only be used on spaceflights of long duration, but may even be cultivated on future space stations and lunar and planetary bases. Particularly interesting are the studies of photoreactivation in higher plants which have been performed by various members of the Institue of Biophysics [515, 540, 541, 595, 596]. These studies are described in the Exobiology section of the present report.

FOOD FOR SPACEFLIGHT

The problem of food for spaceflight can be divided into two major categories: food for spaceflights of short duration (under 25 days), and food for prolonged spaceflights (on which the regeneration of wastes and the growing or synthesis of food will be involved). The problems of food for short-range spaceflights include the calculation of daily calorie and vitamin requirements and the solution of difficulties created by weightlessness. For some reason, comparatively few articles on this subject have been published and many of these which have appeared in newspapers or popular magazines. V. Malkin (who is undoubtedly the ubiquitous V. B. Malkin) deals with this problem in general terms. He describes the jelly-like compositon used for feeding the dogs Belka and Strelka, and also discusses hydroponics and algae. He states that the great difficulties encountered in creating a closed ecological system utilizing algae, have led some scientists to assume that in order to create a reliable closed ecological system, it will be more realistic to supplement the biological system with chemically synthesized foodstuffs [399].

A. S. Ushakov and V. P. Bychkoc have concerned themselves with the food problem to the extent of writing a review paper on Soviet, U. S., and Japanese concepts on the nutritional problems of spaceflight [625]. I. S. Balakovskiy, L. I. Karpova, and S. F. Simpura apparently were responsible for calculating the food and water requirements for dogs in spaceflight and for devising automatic equipment for feeding the animals. It is also probable that they themselves trained the animals in the use of these devices. These devices and methods were used for the dog Layka on Sputnik-II and the dogs Belka and Strelka on the Second Orbital Spaceship [63]. Late in 1961, K. Barykin described the food used by the first two Soviet cosmonauts as being packed in hermetically sealed tubes containing about 170 grams of nourishment each. The tubes were warmed by a battery-operated heater [77]. A. M. Genin, N. N. Gurovskiy, M. D. Yemel'yanov, P. P. Saksonov, and V. I. Yazdovskiy, in their book Chelovek v kosmose (Man in Space), describe the food rations used by Nikolayev and Popovich. They also describe the polyethylene bags equipped with special mouthpieces which were used by the cosmonauts for drinking water. There is no way of knowing, however, to what extent these authors were involved with the design of space food and water equipment [197]. Yu. F. Udalov has apparently investigated the diet and vitamin requirements of cosmonauts [622]. N. S. Zayko, M. I. Kuznetsov, and N. A. Chelnokova, working at the Laboratory of Physiology and Pathology of Sensory Organs of the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences, have performed a study of the effects of prolonged respiration of pure oxygen on gustatory sensitivity and appetite in man [710].

The problem of providing food for spaceflights of long duration is a more challenging one. Two or three years ago, the planners of life support systems for long-range spaceflights felt that green algae would have to be an essential element of any closed ecological system, and a number of studies were therefore made of the nutritional value of Chlorella and other algae.

One such study was performed by N. N. Boyko, V. P. Bychkov, Yu. I. Kondrat'yev, and A. S. Ushakov. They felt that among the many attractive properties of these algae is their ability to change their chemical composition if the mineral content of the growth medium is changed [106]. N. M. Sisakyan, E. N. Bezinger, and M. G. Shaposhnikova also made a protein analysis of chlorella (amino-acid composition), in order to evaluate its usefulness as food for spaceflight [579]. At the Institute of Physiology of the Academy of Sciences USSR, Professor N. N. Sirotinin has been performing experiments with algae and mollusks, which have potential value as food for spaceflight [359]. N. Gurovskiy and M. Gerd predicted that food for long-range spaceflights will consist of Chlorella, zooplankton, mollusks, and possibly fungi. Mollusks and zooplankton will supply the needed animals proteins. Zooplankton will be cultivated together with Chlorella [739]. K. S. Akhlebininskiy, V. P. Bychkov, I. A. Il'ina, Yu. I. Kondrat'yev, and A. S. Ushakov have investigated the possibility of raising chickens in long-range spaceflights. Chickens are considered practical because they would provide the cosmonauts with fresh meat and eggs and could be fed algae and food wastes. The article goes into some detail in an attempt to demonstrate that chicken farming in space is feasible [11]. Yu. Ye. Sinyak has made a study of the possibility of physical and chemical synthesis of carbohydrates in spaceships [561]. As noted above, articles on these problems have not been very numerous in Soviet open literature. Perhaps this is an indication of the fact that until the basic problem of providing a reliable air regeneration system is solved, the problem of food is academic as far as long-range spaceflights are concerned.

LIFE SUPPORT SYSTEMS

Because of the Soviet proclivity for secrecy in all matters relating to development of hardware, very little information is available on the materials, structural details, and equipment subsystems which have gone into the design and outfitting of Soviet space cabins and life support system. The problems facing Soviet life scientists in the design and development of life support systems can be divided into two major categories: those presented by systems intended for flights of short duration (where sufficient supplies of oxygen, food, and wate can be taken along), and those presented by systems for longer flights (25 days or more), on which air and water must be recycled or regenerated. Now that they have been successfully solved, the problems of short-term life support seem simplicity itself in comparison with the complexities of setting up reliable closed ecological systems [246].

Life support for animals

Although no information was available at the time, we now know that V. I. Yazdovskiy, A. V. Pokrovskiy, and A. D. Seryapin were responsible for the life support systems for the animals who were sent into the upper layers of the atmosphere in the days before orbital flights [666]. In addition, we now know the names of the leaders who devised the life support system used for Layka on the Sputnik-II experiment. O. G. Gazenko, V. I. Yazdovskiy, and V. N. Chernigovskiy were closely associated with the design operation of the life support system for Layka [189]. The design and testing of the airtight space cabin for Layka was the responsibility of A. M. Bakhramov, with Yazdovskiy acting as consultant [59]. A. D. Seryapin seems to have had the primary responsibility for the air regeneration system in the sealed cabin of Sputnik-II [537]. The problem of supplying Layka with food and water under spaceflight conditions was apparently the responsibility of I. S. Balakhovskiy, L. I. Karpova, and S. F. Simpura [63]. O. G. Gazenko and A. A. Gyurdzhian worked on the restraint system and the placement of the biosensors for registration of physiological functions for Layka [187]. Gazenko and Gyurdzhian also worked on the AUS-1 (sanitary device for female dogs) used for the collection of waste aboard Sputnik-II, together with G. A. Zakhar'yev, who may have been the engineer who constructed the AUS-1 according to Gazenko's and Gyurdzhian's specifications [188]. B. G. Buylov and R. G. Gryuntal' were the biotelemetric specialists who are mainly responsibile for the equipment used for the Layka experiment on Sputnik-II [118]. Apparently I. V. Baranovskaya collaborated with A. A. Gyurdzhian in the design and development of food and water containers and facilities for smaller animals and living organisms used on the orbital spaceships [65, 66].

Life support for man

A. M. Genin appears to be the chief Soviet spokesman on life support systems for both short-term and long-term flights. Whether Genin is the actual "boss" of research and development of life support systems in the USSR is not definitely known. What is significant, however, is that he headed the team consisting of himself, O. G. Gazenko, and N. P. Sergeyev which presented a paper describing the principles of creating an artificial environment for the Vostok spaceships at the International Symposium on Environmental Problems of Man in Space, in Paris in October 1962 [196]. A. M. Genin was also the principal author with N. N. Gurovskiy, M. D. Yemel'yanov, P. P. Saksonov, and V. I. Yazdovskiy of the book Chelovek v kosmose (Man in Space), which is largely devoted to life support systems for manned spaceflight [197]. It was also A. M. Genin who wrote the only article dealing exclusively with the principles of the formation of artificial environments for spaceship cabins in volume 3 of the very official Problems of Space Biology [198]. In dealing with the subject, Genin gives much attention to the difficulties of creating a closed ecological system for the regeneration of air and water, which is considered by Soviet space scientists to be an absolute must for flights of long duration. N. M. Sisakyan also pointed out that the Soviet space team regards the development of a closed ecological system as the most serious single problem obstructing man's path to the conquest of the planets [580]. V. I. Yazdovskiy, outlining the Soviet program in space biology, has also treated the research and development of life support systems for man as a very important part of the program [675]. Yazdovskiy discusses this problem from two viewpoints, one assuming a closed ecological cycle involving man, plants, and animals in small cabins, and the other assuming the use of physical and chemical methods of regenerating the atmosphere and other elements of the spaceship cabin environment.

Life support for long duration

It is obvious that the problem of providing adequate life support systems for long-range spaceflights is a multisided one requiring the participation of a wide diversity of specialists. Methods for the automatic culture of algae for air regeneration and food production, and the work done toward the development of artificial substrata for hydroponic cultivation of higher plants, are treated in the section of this report devoted to the Chlorella problem. Some scientists, like A. G. Dianov and A. G. Kuznetsov, are studying the possibility of substituting helium for nitrogen in spaceship cabins [151, 152]. O. G. Gazenko, during his visit to San Antonio, Texas in November 1964, indicated that although to date Soviet scientists have provided normal atmospheres for their cosmonauts, more and more Soviet scientists are swinging to the modern view that future flights of long duration may have to rely on helium atmospheres at pressures different from sea level.

While it seems obvious that the Soviet scientists have not yet developed a biological regenerative system for long-range spaceflight, there is much evidence that individual teams are working on peripheral aspects of this problem. Thus, a team consisting of I. S. Breslav, A. G. Zhironkin, E. A. Konza, M. I. Mityushov, A. D. Nozdrachev, Ye. N. Salatsinskaya, G. V. Troshikhin, and A. M. Shmeleva has been studying the effects on mice of a closed environment with an air rengeration system [108]. Attacking the main problem from a different direction, B. G. Grishayenkov, L. L. Zablotskiy, O. F. Ostapenko, Yu. M. Semenov, and A. G. Fomin have been studying the problem of oxygen regeneration by electrolysis of water under weightless conditions [238]. Another large team, consisting of B. L. Gol'dshvend, B. G. Gusarov, A. G. Lobanov, Yu. Ye. Sinyak, A. P. Tereshchenko, S. V. Chizhov, and V. M. Shilov, has been studying the problem of developing physical and chemical methods for reutilization of wastes. To this end they are considering biological recycling utilizing aerobic and anaerobic bacteria, as well as physical and chemical methods [222, 223]. Their work is apparently still in the initial or theoretical stages, but certain scientists seem already to have been assigned specific tasks. Thus, Yu. Ye. Sinyak and S. V. Chizhov are working on the problem of regeneration of water in spaceship cabins [562]. Yu. Ye. Sinyak is also working on the problem of physical and chemical synthesis of carbohydrates for spaceflights of long duration [561]. Some of these waste disposal and regeneration problems involve combustion of the waste products of human and animal metabolism, and a special team, consisting of S. N. Shorin and V. M. Dapshis, has been working on the physical problem of burning gases in a weightless environment [549].

Spacesuits

Soviet thinking regards spacesuits as an extension of life support systems. They were basically designed to protect and maintain the life of the cosmonauts in case of failure of the cabin system. It is not surprising, therefore, that A. M. Genin, O. G. Gazenko, N. P. Sergeyev, N. N. Gurovskiy, M. D. Yemel'yanov, P. P. Saksonov, and V. I. Yazdovskiy [196, 197], should be the chief spokesmen on this subject. In addition, Soviet "Vostok" type spacesuits have been described by F. V. Romanov [506]. Whether or not Romanov is the designer or developer of spacesuits has not been determined for lack of subsidiary evidence. In view of the Soviet attitude that a spacesuit is essentially a life support capsule within the spaceship cabin, it should be assumed that if Genin is really the man in charge of life support systems, he must also be in charge of the design and development of spacesuits [769].

HUMAN ENGINEERING

The amount of Soviet open literature encountered on the subject of spaceflight-oriented human engineering, or engineering psychology as the Soviets call it, has been very small. The number one man in the area appears to be V. G. Denisov, who, together with I. T. Akulinichev, presented a paper on the problems of engineering psychology applied to conditions of spaceflight at The International Symposium on Basic Environmental Problems of Man in Space held in Paris, France, in October 1962 [12]. According to Denisov, the development of human engineering for spaceflight is based on the assumption that the conquest of the planets is unthinkable without the actual participation of man in spaceflight. Denisov appears to be currently working on various aspects of the man-machine relationship in complex control systems. In this work he is associated with A. P. Kuz'minov and V. I. Yazdovskiy [147, 148]. Yu. Ye. Kiselev has been studying the quantitative evaluation of the operator's reliability in the man-machine system [308]. V. A. Popov and A. S. Khachatur'yants have been studying the reactions of organisms to the information content of stimuli [494]. V. A. Yegorov has studied changes in the capacity of information clearance of the central nervous system of man during the process of habit formation while operating flight simulators [682]. V. A. Yegorov has also been working with N. A. Chekhonadskiy on problems of the application of the theory of random functions to the field of space biology and medicine [681]. V. A. Kozhevnikov and L. A. Chistovich have been making studies of human speech processes with a view to designing automatic human speech decoding systems [357]. And last of all, but definitely falling within the sphere of engineering psychology as defined by Denisov, should be mentioned the work performed by V. V. Zefel'd on designing the interior decor of spaceship cabins to create surroundings in which the cosmonaut will feel at home [712].

BIOTELEMETRY

Since radiotelemetry serves as a major tool for the biomedical monitoring of spaceflight experiments, it is natural that space-oriented biotelemetry should be an essential part of the Soviet space program. Space-oriented biotelemetry, like medical, sport, and industrial biotelemetry, constitutes one specialized form of biotelemetry. According to V. V. Rozenblat, who is best known for his work in sport and industrial biotelemetry, there are ten laboratories or centers in the USSR which are currently engaged in biotelemetric research [509, 510]. The most important of these centers is located in Sverdlovsk, where the Second Symposium on Radiotelemetry in Physiology and Medicine was held in December 1963 [474]. Many of the leaders of the Soviet bioastronautics community such as O. G. Gazenko, A. A. Gyurdzhian, V. V. Parin, and V. I. Yazdovskiy, have been closely associated with biotelemetric work [187, 469, 671]. These men, however, despite their active role, must be considered users of biotelemetry rather than creators of it.

The field of space-oriented biotelemetry in the USSR today is dominated by two names: R. M. Bayevskiy and I. T. Akulinichev [14]. R. M. Bayevskiy has been closely associated with all of the orbital spaceflights which carried living organisms, and has worked very closely with all of the Soviet scientists who were directly responsible for the various medical and biological spaceflight experiments [15, 37, 180, 427, 469, 474, 671]. There is every reason to believe that Bayevskiy, who is nominally associated with the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR, is probably the chief consultant on biotelemetry for the Soviet spaceflight program [470, 575, 584].

Bayevskiy's work

In addition to his role as a consultant to scientists who are running spaceflight experiments, Bayevskiy's chief contributions have been in the area of information coding for use with communications channels of limited capacity. In his earlier efforts, Bayevskiy developed a system of "integrated" phonocardiography. This technique for transmitting large amounts of information over limited channels is based on separation of the low-frequency envelope by detection and integration of output signals from the biotelemetric amplifier [79]. His subsequent efforts in information coding enabled him to reduce the channels required by a four-channel electromyograph and a four-channel electroencephalograph by a factor of nearly one hundred [78, 85, 88]. Since then Bayevskiy has been working with V. V. Bogdanov, A. D. Voskresenskiy, A. D. Yegorov, and N. A. Chekhonadskiy on the application of mathematical methods to information coding [89] and with Ye. A. Zil'bertal, V. M. Kruzenshtern, and V. R. Freydel', on the utilization of computers in biomedical monitoring [86]. From this it was a natural step for

Bayevskiy, working this time with V. V. Parin, to move on to cybernetic analysis of the problem of information coding for spaceflight [470]. Currently engaged with the problem of probability coding, Bayevskiy is looking forward to the extension of his system of probability coding to systems of coding with prognosis. The mathematical basis for statistical coding of medical data has not yet worked out, but Bayevskiy believes in the eventual introduction of computerized coding using a system [88].

Akulinichev's work

I. T. Akulinichev, the number two man in Soviet biotelemetry, is a Siberian physician who became interested in electrical equipment at the Omsk Medical Institute, where he received his degree in 1941. After World War II, he turned to electrocardiography and gained nationwide reputation in the Soviet Union as the inventor and designer of a series of vector-cardiographs. After 1960 he moved into the area of space medicine, where he could combine his interests in medicine and electronics. His rapid rise in the the Soviet bioastronautics community may be partly due to the fact that Sisakyan (during his historic battle with the Academy of Medical Sciences USSR) may have wanted to build up Akulinichev to counterbalance Bayevskiy (who was closely associated with V. V. Parin) [321]. Since then Akulinichev has been closely associated with the manned spaceflight program and has worked with N. A. Agadzhanyan, K. P. Zazykin, and D. G. Maksimov on methods of fixing electrodes for registering human electrocardiograms during spaceflight [9]. He also worked on improving the biotelemetric systems used aboard Vostok-5 and Vostok-6 [474].

Biotelemetry specialists

It is sometimes difficult to distinguish between the scientists who utilize biotelemetry for their experiments in spaceflight, and the electronic technicians who are directly responsible for developing biotelemetric methods and equipment. One major review article, published in Volume 3 of Problems of Space Biology, deals with the means and methods of biomedical research in spaceflight. This article is devoted almost exclusively to a description, including wiring diagrams, of equipment used for various types of biotelemetry performed during spaceflights [16]. Except for O. G. Gazenko and V. I. Yazdovskiy, the authors of this article are not life scientists. It is probable, therefore, that they represent the main team of electronic and telemetry specialists working for the Soviet space program:

I. T. Akulinichev

L. F. Andreyev

R. M. Bayevskiy

A. Ye. Baykov

B. G. Buylov

R. G. Gryuntal'

K. P. Zazykin

Yu. F. Klimentov

D. G. Maksimov

Yu. G. Merkushkin

A. V. Monakhov

A. P. Petrov

A. D. Ryabchenkov

N. P. Sazonov

R. I. Utyamyshev

V. R. Freydel'

B. G. Khil'kevich

I. S. Shadrintsev

S. B. Shevandina

N. G. Esaulov [16]

This type of article should be contrated with one of the more usual type devoted to what physiological functions were monitored rather than to how they were monitored [15]. In the case of the latter, the names of Akulinichev and Bayevskiy are followed by those of V. Ye. Belay, P. V. Vasil'yev, O. G. Gazenko, L. I. Kakurin, A. R. Kotovskaya, D. G. Maksimov, G. P. Makhaylovskiy, and V. I. Yazdovskiy [15]. It will be seen that most of these are physiologists or medical men who should be considered consumers of the service rendered by biotelemetry [15]. G. V. Altukhov is also involved in biotelemetric monitoring of man in space. His interest seems to be general and theoretical and he deals with the problem from the point of view of information theory [28], but he has also worked with V. I. Yazdovskiy on monitoring of the emotional state of cosmonauts in spaceflight [679]. Altukhov's role in the spaceflight program is not clear, but his importance can be deduced from the fact that he is one of the authors of the very official publication The First Group Spaceflight [584]. Since voice contact should also be considered a kind of telemetric system, the work of the team of I. Ya. Borshchevskiy, G. M. Belyakov, N. N. Gurovskiy, V. S. Kuznetsov, and Ye. M. Yuganov, who studied the reception and transmission qualities of speech under weightless conditions, should also be included in this section [104].

Types of measurements used

As is well known, a large number of methods was used in cosmic biotelemetry. These methods include electrocardiography, seismocardiography, kinetocardiography, phonocardiography, arterial oscillogaraphy, sphygmography, pneumography, electromyography, actography, thermometry, electroencephalo-

graphy, electro-oculography, and measurement of the skin galvanic response [16, 180]. The majority of scientists who performed spaceflight experiments made use of one or more the biotelemetric methods available, but there seems little purpose in listing the consumers. Some scientists, however, were more directly associated with the use of biotelemetry than others. Thus, we should note that it was R. M. Bayevskiy and M. M. Osipova who selected registry points for attaching electrodes for electrocardiograms of dogs during spaceflight experiments [82], while A. R. Kotovskaya worked out a technique for implanting those electrodes [16]. Bayevskiy worked with V. I. Polyakov on recording sphygmograms of dogs in spaceflight [80], and with L. A. Kazar'yan on registering seismograms of dogs in spaceflight [81]. Bayevskiy worked with O. G. Gazenko on recording the cardiovascular reactions of humans during weightlessness [87], but the method of fixing electrodes for the registration of electrocardiograms of humans during spaceflight was worked out by a team consisting of N. A. Agadzhanyan, I. T. Akulinichev, K. P. Zazykin, and D. G. Maksimov [9].

Electroplethysmography for the purpose of registering cerebral circulation of the blood presents a specialized problem. In this area Yu. Ye. Moskalenko is the leading researcher. He designed the electroplethysmograph in the late 1950's while he was still at the Department of Normal Physiology of the First Leningrad Institute imeni Pavlov [425]. He then began to experiment with the possibilities of evaluating cranial hemodynamics during weightlessness under conditions of spaceflight, and worked on this problem with A. I. Naumenko, N. N. Benua, and O. V. Graunov [428, 429]. More recently, working with O. V. Graunov, O. G. Gazenko, I. I. Kas'yan, and A. A. Shurubura, Moskalenko has applied his electroplethysmographic methods to the study of intracranial hemodynamics during prolonged exposure to excess gravities [430, 431]. Ye. A. Kovalenko and V. B. Malkin also worked on cranial hemodynamics and the determination of oxygen tension in brain tissues, but they were interested in the effects of hypoxia and apparently relied on EEGs rather than on electroplethysmography [347].

Other methods and devices

A different kind of biotelemetry was developed by N. N. Zhukov-Verezhnikov and his team of space microbiologists at the Institute of Experimental Biology of the Academy of Medical Sciences USSR. They developed an effective microbiological sensor system, called the AMN-1, based on gas exchange of anaerobic bacteria (spores of Clostridium butyricum). Their second achievement was research on and utilization of the lysogenic phenomenon observed in phage producing E. coli K-12 bacteria, which respond to radiation in space but not to spaceflight stresses such as vibration [721, 723, 726, 727, 728, 730]. The details of this work are given in the section of this report on space microbiology. A device for recording electroencephalograms of human subjects during prolonged rotation has been developed by A. A. Marinichev [405]. V. S. Gurfinkel', V. B. Malkin,

M. L. Tsetlina, and A. V. Khudyakova have been working with automatic analysis devices in which biocurrents are used for continuous monitoring of the physiological condition of the human organism. These devices are equipped with an automatic diagnosis feature, which signals any pathological change. Rhythmic heart action is monitored by a device which measures time intervals between electrocardiogram waves and which is equipped with an automatic processing feature [279]. Numerous other telemetric devices have also been reported, but their specific application for space-oriented experiments has not yet been established. Further on the biotelemetric equipment used in Soviet space experiments is described in a monograph entitled Radioelectronics in Space Medicine by I. T. Akulinichev, R. M. Bayevskiy, K. P. Zazykin and V. R. Freydel' [17].

In addition to the references already cited in this section, a number of other items were encountered on telemetric devices. However, these concern devices whose specific application to space-oriented experiments cannot be established on the basis of the information given in the source. These references are the following: [5, 29, 92, 102, 177, 240, 245, 296, 317, 326, 341, 376, 451, 485, 497, 609, 687, 737, 746, 748, 760, 766].

SELECTION AND TRAINING

The Soviet system for the selection and training of cosmonauts is similar in many ways to that used in our own Mercury Program. There have been many references to various parts of this program in the Soviet press, but the specific equipment and procedures used have never been described with anything approaching the amount of detail that characterized the coverage of the Mercury Program in our own press. In the main, however, both programs boil down to the selection and training of those candidates who are best able to withstand the stresses of spaceflight: acceleration, vibration, noise, weightlessness, hypodynamia, and isolation. In addition, particular emphasis has been laid to vestibular training ever since Titov's flight on Vostok-2.

Because of the secrecy which shrouds the Soviet space program, it is not always easy to identify personnel who are directly concerned with the Soviet program of cosmonaut selection and training. It is possible, however, to identify some of the leaders. Thus, Ye. M. Yuganov [700] and A. V. Lebedinskiy [383] have both been closely identified with problems of vestibular training, while V. I. Myasnikov [227] and V. I. Yazdovskiy [228] must be counted among the leaders in the isolation and hypodynamia studies. It would be a good bet that the work done by A. G. Kuznetsov on decompression and tolerance to low barometric pressures [372, 373] is closely related to the selection and training program. It is also self-evident that much of the work described in the acceleration and weightlessness sections of this report is directly related to the cosmonaut conditioning and training program. On the other hand, the role of scientists like A. A. Koreshkov, who delivered a paper on the Soviet program for preparing cosmonauts for spaceflight with particular emphasis on parachute training [331], and of Z. I. Barbashova, who presented a report on the use of chemical and pharmacological agents as a means for increasing man's resistance to hypoxia and such spaceflight stresses as vibration, weightlessness, and acceleration [71], is not clear. They may be active participants in the selection and training program, or they may be Soviet scientists who are simply interested in these problems. On the other hand, the tests of the tolerance of the respiratory and cardiovascular systems to centrifugation on an 8-m radius centrifuge, performed by A. S. Barer, G. A. Golov, V. B. Zubarin, and Ye. P. Tikhomirov, are obviously very much a part of the official selection and training program [73].

Physical conditioning

The Soviet cosmonaut training program places considerable stress on physical exercise as a means of improving resistance to spaceflight stresses and to certain pathological conditions. One of the more articulate Soviet scientists in this area is A. V. Korobkov, who has investigated the value

of physical training in maintaining mental, motor, and autonomic stability under varying environmental conditions. He has made studies of what takes place in different organs and systems under conditions of hypodynamia and isolation, and considers that the maintainance of motor functions at a high level is an essential part of preparation to prolonged spaceflights [332, 333]. Another researcher who should be mentioned in connection with physical conditioning is L. V. Chkhaidze of the Georgian Institute of Physical Culture in Tbilisi. Chkhaidze has made detailed studies of the coordination of voluntary movements of man in a changed gravitational field [131, 132, 133, 134], and has used the data from his experiments to construct a set of general principals for the special physical training of cosmonauts [130, 135]. It is not known whether Chkhaidze undertook these studies as part of the official selection and training program, but the publication of his articles in Problems of Space Biology is tantamont to acknowledgement of the value of his work has value for the official program.

Animal training

Among the leaders engaged in the selection and training of dogs for spaceflight in the rocket and pre-Vostok experiments should be listed: V. I. Yazdovskiy, V. N. Chernigovskiy, O. G. Gazenko [189], V. S. Georgiyevskiy [186], I. S. Balakhovskiy, L. I. Karpova, S. F. Simpura [63], V. N. Chernov, and V. I. Yakovlev [125]. To this group should be added the name of B. A. Zhuravlev, who studied the formation of new motor habits under weightless conditions. His subjects were the dogs Belka and Strelka, who were passengers on the second orbital spaceship [731].

Vestibular training

The vestibular analyzer has become one of the special problem areas in the selection and training of cosmonauts. A team consisting of A. V. Lebedinskiy, N. I. Arlashchenko, B. B. Bokhov, Yu. G. Grigor'yev, L. N. Kvasnikova, and Yu. V. Farber has been working on a system for selecting and training cosmonauts on the basis of evaluation of the functional state of the vestibular analyzer [383]. Another team, consisting of Ye. M. Yuganov, S. S. Markaryan, I. I. Bryanov, I. A. Sidel'nikov, and R. A. Vartbaronov, has been evaluating the effectiveness of some of the methods of vestibular selection [700]. Ye. M. Yuganov, working with A. I. Gorshkov, has run a number of experiments subjecting humans to short-term weightlessness, Coriolis accelerations, radial accelerations, and galvanic current, in order to evaluate the significance of the vestibular function in the cosmonaut training program [701]. V. V. Baranovskiy, M. D. Yemel'yanov, and A. G. Kuznetsov have been testing vestibular functions in experiments using spe-

cially constructed training devices [67]. V. A. Kislyakov and V. P. Neverov have been studying aftereffect phenomena in the central nervous system after prolonged optokinetic stimulation [309]. S. I. Nudman has studied the effect of rotational training on the conditioned motor reflexes of rats in the Laboratory of Comparative Ontogenesis of Higher Nervous Activity of the Institute of Physiology imeni Pavlov of the Academy of Sciences USSR [446]. V. I. Kopanev and G. V. Altukhov have been studying the effect of statokinetic stimuli (quick head movements, slow rotations, and Corolis accelerations), on certain body functions (EKG, EEG, skin galvanic response, blood pressure, and respiration rate). These methods were developed for use in personnel selection programs and in statokinetic-stability conditioning [29, 329]. A. I. Yarotskin has performed very similar experiments in vestibular training [665].

Still more specific experiments on the vestibular function were performed in animal experiments. Thus, V. T. Khlebas and N. P. Kozhukhar' performed experiments with dogs using a rotating table and a Khilov swing to test the effects of vestibular stimulation on the secretional and motor functions of the stomach. Biopotentials were recorded by means of leads introduced into the stomach using Basov's fistula [300]. A. S. Dmitriyev and Ye. V. Burko studied the effects of vestibular stimulation (rotation on a turntable) on the smooth muscles and blood vessels of the small intestine of dogs following resection of the spinal cord and the vagus, cervical sympathetic, and splanchnic nerves [153]. R. Kh. Gambarova rotated rabbits in a Barany chair to to test the role of the vestibular organ in regulation of the blood sugar level [176].

Spatial perception and orientation

Spatial orientation is considered by Soviet scientists to be an important part of their training program. M. D. Yemel'yanov and Ye. M. Yuganov have been working on problems of spatial perception and orientation, and have devised a number of procedures for testing the visual, vestibular, and proprioceptive senses. Experiments were performed in order to determine the interaction of the vestibular and proprioceptive senses in the absence of visual orientation [684]. V. V. Baranovskiy and I. D. Semikopnyy have been studying the interaction of the vestibular and visual analyzers. They developed a method for quantitative determination of individual tendencies towards spatial orientation illusions evoked by the observation of moving objects. The test is intended as a guide for the selection of pilots [70]. B. V. Anokhin, working in the Laboratory of Physiology and Pathology of Sensory Organs of the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences USSR, has conducted experiments on the correspondence between retinal reactions and the magnitude of conditioned and unconditioned stimuli [35]. V. D. Nebylitsyn has been studying individual differences in bioelectric brain potential reactions to rhythmic light stimuli [438]. V. D. Glezer, I. I. Tsukkerman, and T. M. Tsykunova have been studying the relationship of visual recognitive ability to brightness. They were particularly interested in the

maximum amount of information which can be absorbed by the brain through the visual system per unit of time [215]. The last study, while still in the area of perceptual physiology, is obviously oriented in the direction of human engineering.

Hypodynamia and isolation studies

Another major area of the Soviet cosmonaut selection and training program involves hypodynamia and isolation studies. A. L. Myasnikov, directing one of the larger teams working in this area consisting of R. M. Akhrem-Akhremovich, L. I. Kakurin, Yu. T. Pushkar', N. M. Mukharlyamov, V. S. Georgiyevskiy, Yu. N. Tokarev, Yu. A. Senkevich, B. S. Katkovskiy, A. N. Kalinina, M. A. Cherepakhin, V. A. Chichkin, V. K. Filosofov, and P. G. Shamrov, has explored the effects of prolonged hypodynamia (or hypokinesia) on the circulation of blood in humans [433]. Another man of the same name, V. I. Myasnikov, worked with F. D. Gorbov and V. I. Yazdovskiy on the effects of prolonged isolation on various physiological functions. They paid particular attention to neuropsychiatric changes, since these made it possible for them to determine and establish strain and fatigue limits for conditions of prolonged isolation [227, 228]. Gorbov, incidentally, is probably better known for his studies in the field of space psychology. V. I. Myasnikov, sometimes working alone and sometimes with G. V. Izosimov, has done a number of studies on the effects of prolonged isolation and sensory deprivation on the central nervous system [272, 4334]. V. I. Myasnikov has also studied the effect of isolation on motor reactions of adult males, using electromyograms of the fingers to record motor reactions to light stimuli [435].

The work capacity of cosmonauts under simulated conditions of the Vostok cabin was investigated by L. I. Kakurin and Yu. N. Tokarev [275]. These ground experiments were conducted in order to determine work capacity, with an eye to future structuring of space crews. Additional experiments were performed under similar conditions by L. I. Kakurin with B. S. Katkovskiy, A. N. Kozlov, and N. M. Mukharlyamov [274]. M. A. Gerd, also working with subjects in simulated Vostok cabins, investigated the biochemical reations of the muscle tissue to conditions of adynamia [201]. A. P. Kuz'minov, V. F. Onishchenko, and M. M. Sil'vestrov studied the retention of habits for transmitting information under conditions of prolonged isolation [368]. Ye. I. Chazov and V. G. Ananchenko studied anticoagulation mechanisms during prolonged hypodynamia [121]. Yu. V. Vanyushina studied the effects of hypodynamia on the cardiovascular system [626]. N. A. Agadzhanian and A. G. Kuznetsov have likewise been concerned with the reactions of the organism during relative adynamia and isolation [6]. N. Ye. Panferova has studied the effects of hypodynamia on the circadian rhythm of physiological functions [455, 456]. V. A. Shkurdoda has tested the effects of brief physical training on the survival rates of rats during prolonged hypodynamia and isloation [548]. N. A. Rokotova, working with I. D. Bogina, O. P. Bolotina, T. M. Kucherenko, Ye. S. Rogovenko, and R. L. Sheykin, has studied the effect of prolonged

limitation of motor activity on the viability of monkeys. The restraint system was designed by Sheykin, and the work was performed at the monkey colony in Sukhumi [505]. V. A. Alidzhanova has studied the combined effects of repeated action of high temperature and isolation on the mineral salt content of body fluids [22]. These hypodynamia and isolation studies, most of which have been performed within the last two years, indicate the concern of Soviet scientists with this problem, and serve as a measure of their interest in prolonged spaceflights.

Psychological testing and space psychology

The field of selection and training of cosmonauts quite naturally extends into the area of psychological testing and hence, into a new discipline which its practitioners call space psychology. The work of V. I. Yazdovskiy, G. V. Altukhov, V. Ye. Belay, A. D. Yegorov, and V. I. Kopanev on nervous and emotional strain in cosmonauts during spaceflight falls into this area [679]. To this area also belong the studies on regularities in the appearance of accelerational gravity sensations made by Ye. A. Derevyanko and V. N. Myl'nikov [149]. A number of theoretical articles concerning psychological tests and standards also belong here, such as the criteria for cosmonaut selection set up and analyzed by V. D. Nebylitsyn and B. M. Teplov [437], and the evaluation between psychological testing and actual learning and performance carried out by B. L. Pokrovskiy, T. I. Zhukova, and V. P. Zukhar' [486].

In the field of space psychology proper (i.e., studies by scientists who refer to their work as "cosmic psychology"), we find a series of articles whose chief function appears to be the attempt to describe and define the field and problems of space psychology. The earliest of these is an article on "Psychological Problems of Spaceflight," written by K. K. Platonov in early 1959 [483]. This was followed by an article entitled simply "Space Psychology," written by F. D. Annenskiy in 1961 [34]. This was followed by two articles on cosmic psychology by F. D. Gorbov [225, 226] and a single article by V. D. Gorlov [230] on the same subject. It should be noted that these articles have become progressively more difficult to understand. One unsympathetic Soviet observer at an international meeting commented that they reminded him "of a process akin to the rubbing of the navel against infinity." This judgement of space psychology is probably a little harsh, but it is nonetheless true that articles on space psychology tend to be singularly wordy and unclear, leaving the reader with the impression that the psychologists are trying to carve a new academic discipline out of very thin air.

CONCLUSIONS

Although a large amount of information has been assembled on the activities of the Soviet bioastronautics and manned spaceflight programs, it is felt that much more can be done to clarify the picture more fully. For one thing, the 700-odd references assembled for the purposes of this report take us only through the middle of 1964. Since the number of articles appearing in Soviet open sources on bioastronautics and manned spaceflight has been increasing each year, it should come as no surprise that since mid-1964, enough additional material has appeared that it is not too early to begin an immediate updating of the present report. For one thing, two new collections of articles were published late in 1964. The first of these is called "Problems of Radiation Safety in Spaceflgihts: Physical and Biological Research Using High-Energy Protons." The second collection, published by the Institute of Biophysics of the Academy of Sciences USSR, is entitled "Effects of Ionizing Radiation and Dynamic Factors on the Functions of the Central Nervous System: Problems of Space Physiology." In addition, volume four of the series Problems of Space Biology is scheduled to appear early in 1965. The publication of these three collections alone should supply a sufficient amount of information for a fairly substantial supplementary report. If we add to this the information appearing in the periodical literature, including data from the Voskhod flight, and from the papers that Soviet scientists are scheduled to present at the COSPAR meeting and at The Second International Symposium on the Basic Environmental Problems of Man in Space (both of which are scheduled for the first half of 1965), it becomes fairly obvious that the updating of this report should begin immediately.

The existing materials, including those presented in this report, should be subjected to a more intensive analysis if we are to obtain a clearer picture of the dynamics of the Soviet bioastronautics and manned spaceflight research programs. A number of obvious approaches suggest themselves. For one thing, the series of monographs devoted to manned spaceflight warrants a more thorough study of the shifts in manned spaceflight procedures and technology. Secondly, a comparison of the leading articles in successive volumes of Problems of Space Biology, should give us an insight into changes in the relative importance of various problems in the basic research program. Thirdly, additional light can be shed on the dynamics of research emphasis by reviewing changes in the compositions of the Soviet delegations which have been sent to the various international astronautical meetings and by the changes in the composition of the editorial boards of individual volumes of Problems of Space Biology and the group authors of the monographs on manned spaceflight.

Since a large amount of information has been accumulated on individual Soviet scientists in the course of preparing this report, it is felt that a useful service can be provided for the American bioastronautics community by publishing the currently available data in the form of biographic sketches of individual scientists, listed alphabetically, thus providing a "Who's Who in Soviet Bioastronautics."

APPENDIX: LIST OF INSTITUTES AND SCIENTISTS ASSOCIATED WITH THE SOVIET BIOASTRONAUTICS EFFORT

INSTITUTES OF THE ACADEMY OF SCIENCES USSR

Institute of Biochemistry (imeni A. N. Bakh), Academy of Sceinces USSR, Moscow

Krasnovskiy, A. A. [358]
Drozdova, N. N. [358]
Oparin, A. I. (Director) [742]
Sisakyan, N. M. [572], [566] (1960)
Mosolova, I. M. [572]
Odintsova, M. S. [566] (1960)

Institute of Atomic Energy (imeni Kurchatov), Academy of Sciences USSR, Moscow

Alikhanyan, S. I. [26], [686]
Yerokhina, L. I. [686]

Institute of Biophysics, Academy of Sciences USSR, Moscow

Apanasenko, Z. I. [43]
Kuznetsova, M. A. [43]
Arsenyeva, M. A. (Dept. of Biological Sciences, Laboratory of Radiation Genetics) [53]
Tinyakov, G. G. [53]
Breslavets, L. P. [112] (1956), [113] (1963)
Berezina, N. M. [112] (1956)
Shibrya, G. I. [112] (1956)
Romanchikova, M. L. [112] (1956)
Byzov, A. L. [120]
Mazokhin-Porshnyakov, G. A. [120]
Glembotskiy, Ya. L. (Laboratory of Radiation Genetics) [161], [210]
Abeleva, E. A. (Laboratory of Radiation Genetics) [161], [210]
Lapkin, Yu. A. (Laboratory of Radiation Genetics) [161], [210]
Parfenov, G. P. (Laboratory of Radiation Genetics) [161]
Dubinin, N. P. [162]
Khvostova, V. V. [303]
Nevzgodina, L. V. [303]
Meyzerov, Ye. S. [420]
Sidorov, B. N. [554]
Sokolov, N. N. [554]
Tageyeva, S. V. [612], [613]
Pavlova, I. P. [612]
Brandt, A. B. [612], [613]
Korshunova, V. S. [613]
Generozova, I. P. [613]

Institute of Biophysics (Continued)

Shabadash, A. L. [539] (1961)
Zelikina, T. I. [539] (1961)
Agracheva, N. D. [539] (1961)
Yorbus, A. L. [688], [689], [690], [691]

Institute of Cytology, Academy of Sciences USSR, Leningrad

Lozina-Lozinskiy, L. K. (Laboratory of Cell Adaptation) [389], [744]
Rapoport, I. A. [489] (1943)

Institute of Evolutionary Physiology (imeni I. M. Sechenev), Academy of Sciences USSR, Leningrad

Botvinnikov, B. A. [105]
Fel'dman, L. A. [105]
Freyman, G. N. [105]
Ginzburg, I. Sh. [105]
Gramenitskiy, P. M. [105]
Ivanov, G. I. [105]
Ivchenko, O. I. [105]
Libin, Yu. M. [105]
Salmanov, L. P. [105]
Rudnyy, N. M. [105]
Brestkin, A. P. [114] (1958)
Moskalenko, Yu. Ye. [426] (1959), [429], [431]
Benua, N. N. [429]
Grannov, O. V. [429], [431]
Gazenko, O. G. [431], [630], [634]
Shurubura, A. A. [431]
Kas'yan, I. M. [431]
Vinnikov, Ya. A. (Vestibular Organ Study) [634]
Bronshteyn, A. A. (Vestibular Organ Study) [634]
Titova, L. K. (Vestibular Organ Study) [634]
Vasil'yev, P. V. [630]
Voskresenskiy, A. D. [630]

Institute of Microbiology, Academy of Sciences USSR, Moscow

Fedorova, R. I. (Spec. Envrionmental Biol.) [164]
Imshenetskiy, A. A. [259], (Director) [742]
Iyerusatimskiy, N. D. [273]
Zabarzina, N. B. [705]
Zhukova, A. I. [717]

Institute of Physiology (imeni I. P. Pavlov), Academy of Sciences USSR, Leningrad

Breslav, I. S. [109], [110], [111]
Chernigovskiy, V. N. [109], [124] (Head)
Zhironkin, A. G. [110]
Konza, E. A. [110]
Salatsinskaya, Ye. N. [110]
Troshikhin, G. V. [110]
Sirotinin, N. N. [359] (1958)
Nevskaya, A. A. (Laboratory of Physiol. of the Visual Analyzer) [440] (1961)
Nudman, S. I. (Laboratory of Comparative Ontogenesis of Higher Nervous Activity) [446]
Verzhbinskaya, N. A. [632]
Yevdokimov, S. A. [687]

Institute of Plant Physiology (imeni K. A. Timiryazev), Academy of Sciences USSR, Moscow

Krylov, A. V. [361]
Shakhov, A. A. [541], [540]
Nichiporovich, A. A. [441] (1961), (Photosynthesis Laboratory) [531], [442]
Semenenko, V. Ye. [442], [526] (1961), [531] (1956, 1959)
Vladimirova, M. G. [442], [531] (1961), [637] (1961), [636] (1961)
Strogonova, L. Ye. [531] (1959)
Bazaitova, L. N. [637] (1961)
Khazanov, V. S. [540]

INSTITUTES OF THE ACADEMY OF MEDICAL SCIENCES USSR

Institute of Experimental Biology, Academy of Medical Sciences USSR, Moscow

Mayskiy, I. N. (Director) [475] (1959), [478], [154]; Laboratory of of Non-Infectious Immunology) [478], [414]; [720] (1961), [726]
Dobrokhotov, V. N. (Head, Laboratory of Histophysiology) [154]; [155]
Kurdyumova, A. G. [154]
Nikanorova, R. I. [155]
Khundanova, L. L. (Laboratory of Non-Infectious Immunology) [415]
Pekhov, A. P. (Head, Laboratory of Genetics of Microogranisms) [726], [477], [478]; (Department of Immunology) [475], [476], [479], [720] (1961)
Zhukov-Verezhnikov, N. N. (Head, Department of Immunology) [475]; [720] (1961), [726]
Yudin, Ye. V. [476]
Besova, T. A. [476]

Institute of Experimental Biology (Continued)

Sychkov, M. S. [476]
Mishchenko, B. A. [478]
Nefed'yeva, N. P. [720] (1961), [726]
Tribulev, G. P. [726]
Rybakov, I. N. [726]
Rybakova, K. D. [726]

Institute of Experimental Pathology and Therapy, Academy of Medical Sciences USSR, Sukhumi

Lapin, B. (Director) [375]

Institute of Experimental Medicine, Academy of Medical Sciences USSR, Leningrad

Fel'berbaum, R. A. [167] (1958)

Institute of Industrial Hygiene and Occupational Diseases, Academy of Medical Sciences USSR, Moscow

Chemnoy, A. B. [10]
Drogichina, E. A. [10]
Ginzburg, D. A. [10]
Metlina, N. B. [10]
Osipova, V. G. [10]
Kuznets, Ye. I. [369], [370]
Kurlyandskaya, E. B. [364], [365], (Head, Radiotoxicological Laboratory) [663]
Avrunina, G. A. [364], [365] (Radiotoxicological Laboratory) [660]
Ponomareva, V. L. [364], [365] (Radiotoxicological Laboratory)
Fedorova, V. I. [364], [365] (Radiotoxicological Laboratory)
Yanovskaya, B. I. [364], [365] (Radiotoxicological Laboratory)
Yarmonenko, S. P. [364], [663], [662], [660]
Govorun, R. D. [365] (Radiotoxicological Laboratory) [660]
Shmakova, N. L. [662]
Shashkov, V. S. [660]

Laboratory for Experimental Physiology of Reanimation of the Body, Academy of Medical Sciences USSR, Moscow

Negovskiy, V. A. (Director) [555], [594], [747]
Soboleva, V. I. [594]

Central Scientific Research Institute of Sanitation and Hygiene (imeni F. F. Erisman), Academy of Medical Sciences USSR, Moscow

Arkad'yevskiy, A. A. [10]
Genkina, A. G. [10]
Kondaurova, Ye. I. [10]
Mel'kumova, A. S. [10]
Rumyantsev, G. I. [10], [560]*
Sinitsyn, S. N. [560]*
Voronova, K. V. [560]*

*Listed in 1964 as: Moscow Scientific Research Institute of Hygiene (imeni F. F. Erisman)

Institute of Normal and Pathological Physiology, Academy of Medical Sciences USSR, Moscow

Anokhin, B. V. (Laboratory of Physiology and Pathology of Sensory Organs) [35]
Ardashnikova, L. I. (Laboratory of General Physiology) [46]
Chernigovskiy, V. N. (Director, Institute of Physiology) [122]
Yazdovskiy, V. I. [694], [678], [668], [667] (1960); (M.D.) [670]
Kas'yan, I. I. [286], [287], [695], [694], [697], [678], [667] (1960)
Marshak, M. Ye. (Laboratory of Physiology and Pathology of Respiration and Blood Circulation) [407]
Parin, V. V. [470], [472]; (Director) [710]
Bayevskiy, R. M. [470]
Meyerson, F. Z. [472]
Yuganov, Ye. M. [695], [694], [697], [667] (1960)
Isakov, I. K. [695]
Afanas'yev, D. V. [695]
Pavlov, G. I. [695]
Asyamolov, B. F. [697]
Kopanev, V. I. [678]
Mansurov, A. P. [668]
Agadzhanyan, N. A. [668]
Tsivilashvili, A. S. [668]
Zayko, N. S. (Laboratory of Physiology and Pathology of Sensory Organs) [710]
Kuznetsov, M. I. (Laboratory of Physiology and Pathology of Sensory Organs) [710]
Chelnokova, N. A. (Laboratory of Physiology and Pathology of Sensory Organs) [710]
Snyakin, P. G., Professor, (Head, Laboratory of Physiology and Pathology of Sensory Organs) [710]
Ardashnikova, L. I. (Laboratory of General Physiology) [46] (1958)

MILITARY AND AVIATION ORGANIZATIONS

Institute of Aviation Medicine, Moscow area

Prutskoy, A. N. [497] (1956)
Pokrovskiy, A. V. (Director in 1957) [767], [750] (1957)

Military Medical Academy (imeni S. M. Kirov), Leningrad

Arbusov, S. V. [45] (1957)
Anosova, E. M. [45] (1957)
Aver'yanov, V. A. [55] (1960, 1962)
Bardina, R. A. (Department of Normal Anatomy) [72]*
Kuznetsov, V. I. [374]
Kushakovskiy, M. S. [374]
Belov, I. [746]

*Affiliated also with First Leningrad Medical Institute (imeni I. P. Pavlov)

INSTITUTES OF THE SIBERIAN DEPARTMENT OF THE ACADEMY OF SCIENCES USSR

Institute of Cytology and Genetics, Siberian Department of the Academy of Sciences USSR, Novosibirsk

Kerkis, Yu. Ya. [162], [294]
Lebedeva, L. I. [162]
Ronichevskaya, G. M. [294]
Rukavichnikov, Yu. M. [294]
Naumenko, Yu. N. [294]

Institutes of Experimental Biology and Medicine, Siberian Department of the Academy of Sciences USSR, Novosibirsk

Gurfinkel', V. S. [241] (1959)
Isakov, P. K. [241] (1959)
Malkin, V. B. [241] (1959)
Popov, V. I. [241] (1959)

INSTITUTES OF ACADEMIES OF SCIENCES OF UNION REPUBLICS

Institute of Physiology (imeni A. A. Bogomolets), Academy of Sciences Ukrainian SSR, Kiyev

Gurevich, M. I. (Laboratory of the Physiology of Blood Circulation) [240]
Golov, D. A. (Laboratory of the Physiology of Blood Circulation) [240]
Kondratovich, M. A. (Laboratory of the Physiology of Blood Circulation) [240]
Kozak, V. A. (Laboratory of the Physiology of Blood Circulation) [240]

Physio-technical Institute of Low Temperatures, Academy of Sciences Ukrainian SSR

Lysenko, S. [259]

Institute of Physiology, Academy of Sciences Georgian SSR, Tbilisi

Mchedlishvili, G. I. [416]

Pamir Botanical Garden, Academy of Sciences Tadzhik SSR

Glagoleva, T. A. [206]
Ostapovich, L. F. [540]

Botanical Institute, Academy of Sciences Uzbek SSR

Muzafarov, A. M. (Director of Chlorella Studies, 1957-1962) [93]
Kostina, V. P. [339]

Institute of Regional Experimental Medicine, Academy of Sciences Uzbek SSR, Tashkent

Abidov, A. A. [477]
Makhkamov (Director) [477]

STATE UNIVERSITIES

Moscow State University (imeni M. V. Lomonosov), Moscow

Kakushkina, M. L. [277]
Korolev, N. P. [277]

Moscow State University (Continued)

Kudryashov, Yu. B. [277]
Davydova, N. V. (Biology and Soil Sciences Department) [141]
Pospelova, V. V. (Biology and Soil Sciences Department) [141]
Telichenko, M. M. (Biology and Soil Sciences Department) [141]
Kotlyar, B. I. (Department of the Physiology of Higher Nervous Activity) [341]
Tageyeva, S. V. [611] (1961)
Brandt, A. V. [611] (1961)
Korshunova, V. S. [611] (1961)

Leningrad State University (imeni A. A. Zhdanov), Leningrad

Funtikov, B. A. (Department of Biophysics) [713]

Ural State University (imeni A. B. Gor'kiy), Sverdlovsk

Zhukov, V. G. [716]
Levin, Yu. S. [716]
Rybin, I. A. [716]

INSTITUTES OF THE MINISTRY OF HEALTH USSR

Moscow Scientific Research Institute of Experimental Surgical Equipment and Instruments, Ministry of Health USSR, Moscow

Anan'yev, M. G. (Director) [33] (1959); [768] (1959)
Antoshina, N. V. [33] (1959)

Central Scientific Research Institute of Health Resorts and Physical Therapy, Ministry of Health USSR, Moscow

Shchepoteva, Ye. S. [547] (1961)
Ardashnikov, S. N. [547] (1961)
Lur'ye, G. Ye. [547] (1961)
Rakhmanova, T. B. [547] (1961)

Central Institute of Hematology and Blood Transfusion, Ministry of Health USSR, Moscow

Nemenova, N. M. [439]
Manteyfel', V. M. [439]
Chernov, G. A. [439]

Central Sceintific Research Institute of Medical Radiology, Ministry of Health USSR, Moscow

Bychkovskaya, I. B. (Department Exp. Morphology) [119] (1961)
Strelin, G. S. (Prof., Head Department Exp. Morphology) [119] (1961)
Rusanov, A. M. [512]
Mozharova, Ye. N. [512]
Komarova, R. S. [512]

All-Union Scientific Research Chemical and Pharmaceutical Institute (imeni S. Ordzhonikidze), Ministry of Health USSR, Moscow

Suvorov, N. N. [370]

INSTITUTES OF THE RSFSR MINISTRY OF HEALTH

Leningrad Institute of Industrial Hygiene and Occupational Diseases, Ministry Of Health RSFSR, Leningrad

Agashin, Yu. A. [10]
Konikova, G. S. [10]

Leningrad Medical Institute of Sanitation and Hygiene, Ministry of Health RSFSR, Leningrad

Andreyeva-Galanina, Ye. Ts. [10]
Artamonova, V. G. [10]
Bauer, I. G. [10]
Vozhzhova, A. I. [10]
Burlova, L. Ya. [10]
Ivanov, A. Ya. (Director) [10]
Karpova, N. I. [10]
Lebedeva, A. F. [10]
Stom, M. F. [10]

Leningrad Scientific Research Institute for Radiation Hygiene, Ministry of Public Health RSFSR, Leningrad

Tyukov, D. M. [600]

MUNICIPAL MEDICAL INSTITUTES

First (Order of Lenin) Moscow Medical Institute (imeni I. M. Sechenev), Moscow

Gur'yev, A. F. (Department of Gen. Hygiene) [244]
Yurin, R. F. (Department of Path. Physiol.) [704]
Pavlenko, S. M. (Chairman, Department of Path. Physiol.) [704]

First Leningrad Medical Institute (imeni I. P. Pavlov), Leningrad

Bardina, R. A. (Department of Normal Anatomy) [72]*
Moskalenko, Yu. Ye. (Department of Normal Physiology) [425] (1957)
Naumenko, A. I. (Department of Normal Physiology) [425] (1957)

*Affiliated also with Military Medical Academy (imeni S. M. Kirov)

Chelyabinsk Medical Institute, Chelyabinsk

Gil', L. T. [202] (1961)
Levina, Ye. S. [202] (1961)
Vovki, A. S. [202] (1961)
Posledov, F. F. [202] (1961)

Kalinin Medical Institute, Kalinin

Semenov, N. V. (Director, Department of Physiol.) [594]
Gorokhovskiy, B. O. (Department of Physiol.) [594]

Kuybyshev Medical Institute, Kuybyshev

Madorskiy, V. A. [10]

Turkmen Medical Institute, Ashkhabad

Bayryyev, Ch. [742]
Mamedov, S. [742]

Yerevan Medical Institute, Yerevan

Sarkisyan, A. A. (Prof. of Pathophysiology) [641]
Khachutryan, S. A. [641]
Zakaryan, A. B. [641]

OTHER INSTITUTES (of undetermined jurisdiction)

All-Union Scientific Research Institute of Antibiotics, Moscow

Kapitonova, O. N. [280]

All-Union Scientific Research Institute of Medical Instruments and Equipment, Moscow

Kapitanov, R. A. [279]

All-Union Scientific Research Institute of Railway Hygiene, Ministry of Transportation USSR

Bordukov, A. V. [10]
Volkov, A. M. [10]

Central Institute for the Advanced Training of Physicians, Moscow

Suvorov, P. M. [603], [604]

Electromechanical Institute of the State Committee on Automation and Machine Building, Council of Ministers USSR

Trubitsyna, G. A. [687]

Institute of Hygiene, Moscow

Kandrov, I. S. (Physiological Laboratory) [278]
Rapoport, K. A. (Physiological Laboratory) [278]

Moscow Medical Stomatological Institute, Moscow

Tikhomirov, I. I. (Department of Normal Physiol.) [616], [617]
Snyakin, P. G. (Head, Department of Normal Physiol.) [616]
Beletskiy, G. N. (Director) [617]

Sceintific Research Institute of Neurosurgery (imeni A. L. Polenov), Leningrad

Grachev, K. V. [236]
Stepanova, T. S. [600]

State Institute of Physical Culture (imeni P. F. Lesgaft), Moscow

Gandel'sman, A. B. [177]

Scientific Research Institute of Occupational Physiology, Donetsk

Navakatikyan, A. O. (Laboratory for Clinical Physiology) [436]
Lebedeva, I. N. (Laboratory for Clinical Physiology) [436]
Blagoveshchenskaya, I. N. (Laboratory for Clinical Physiol.) [436]
Pevnyy, S. A. (Laboratory for Clinical Physiology) [436]

Ukrainian Institute of Industrial Hygiene and Occupational Diseases, Khar'kov

Abramovich-Polyakov, B. K. [10]
Tarasova, A. V. [10]
Yakubovich, G. G. [10]

Georgian Institute of Physical Culture, Tbilisi

Chkaidze, L. V. [129] (1960); [131] (1962)

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2. Abeleva, E. A., et. al. Iskusstvennyye sputniki Zemli, no. 13, 1962 119-123.

3. Abyzov, S., and A. Imshenetskiy. Paper presented at the 5th International Space Science Symposium (COSPAR), Florence, Italy, 8-20 May 1964.

4. Afanas'yev, Yu. I. IN: Aviatsionnaya i kosmicheskaya meditsina; materialy konferentsii 1963 goda (Aviation and space medicine; materials of the 1963 conference). Moskva, 1963. 40-44.

5. Afanas'yeva, R. F., et al. Gigiyena i sanitariya, no. 11, 1963, 63-66.

6. Agadzhanyan, N. A., and A. G. Kuznetsov. IN: Nauchnaya sessiya, posvyashchennaya 5-oy godovshchine zapuska pervogo isskusstvennogo sputnika Zemli (Scientific session commemorating the 5th anniversary of the launching of the first artificial Earth Satellite). Moscow, 1962. 25-27.

7. Agadzhanyan, N. A., and A. R. Mansurov. Byulleten' eksperimental'noy biologii i meditsiny, v. 53, no. 4, Apr 1962, 42-46.

8. Agadzhanyan, N. A., et al. Voyenno-meditsinskiy zhurnal, no. 12, 1958, 45-48.

9. Agadzhanyan, N. A., et al. IN: Problemy komicheskoy biologii, t. 1 (Problems of space biology, v. 1). Moskva, Izd-vo AN SSSR, 1962. 145-151.

10. Agashin, Yu. A., and V. G. Artamonova. Gigiyena i sanitariya, no. 5, 1962, 104-106.

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12. Akulinichev, I. T., and V. G. Denisov. Paper presented at the International Symposium on Basic Environmental Problems of Man in Space, Paris, France, 29 October-2 November 1962.

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15. Akulinichev, I. T., et al. IN: Aviatsionnaya i kosmicheskaya meditsina; materialy konferentsii 1963 goda (Aviation and space medicine; materials of the 1963 conference). Moskva, 1963. 6-8.

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18. Aleksandrov, A. Meditsinskiy rabotnik, 31 Dec 1957, 3.

19. Aleksandrov, N. Nauka i zhizn', no. 12, 1960, 2-6.

20. Alekseyeva, O. G. Iskusstvennyye sputniki Zemli, no. 13, 1962, 63-77.

21. Alekseyeva, O. G., and A. P. Volkova. IN: Problemy kosmicheskoy biologii, t. 1 (Probelms of space biology, v. 1). Moskva, Izd-vo AN SSSR, 1962. 181-189.

22. Alidzhanova, V. A. AN UzbSSR. Otdeleniye biologicheskikh nauk. Voprosy biologii i krayevoy meditsiny, no. 4, 1963, 369-374.

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